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Tsumura

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(54) **WIRELESS COMMUNICATION SYSTEM AND TERMINAL-DEVICE AUTHENTICATION METHOD IN WIRELESS COMMUNICATION SYSTEM**

(75) Inventor: **Naoki Tsumura**, Kanagawa (JP)

(73) Assignee: **RICOH COMPANY, LIMITED**, Tokyo (JP)

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

H04W 12/06 (2009.01)
H04L 9/08 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H04W 12/06*** (2013.01); ***H04L 9/0822*** (2013.01); ***H04L 9/3228*** (2013.01); ***H04L 63/0478*** (2013.01); ***H04L 63/107*** (2013.01); *H04L 2209/80* (2013.01)

(58) **Field of Classification Search**

CPC combination set(s) only.
See application file for complete search history.

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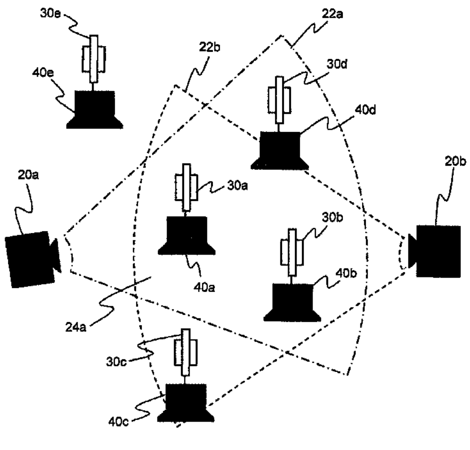
Primary Examiner — Beemnet Dada

(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

A wireless communication system includes code transmitters (**20***a*, **20***b*) each configured to transmit a time-varying code; code receivers (**30***a*, **30***b*) each configured to receive the time-varying codes transmitted from the code transmitters (**20***a*, **20***b*) and generate a fingerprint based on the received time-varying codes, the fingerprint being unique to a space where the time-varying codes are receivable; and terminal devices (**40***a*, **40***b*) configured to establish wireless communication connection therebetween with authentication. The terminal devices (**40***a*, **40***b*) are connected to the code receivers (**30***a*, **30***b*), respectively. Each terminal device (**40***a*, **40***b*) includes a fingerprint acquiring unit configured to acquire the fingerprint from the code receiver (**30***a*, **30***b*), a wireless communication unit configured to transmit and receive the fingerprint via wireless communication, and an authentication unit configured to authenticate another terminal device if the fingerprint received from the another terminal device matches the fingerprint acquired from the code receiver connected thereto.

10 Claims, 14 Drawing Sheets



(51) **Int. Cl.**

H04L 9/32	(2006.01)
H04L 29/06	(2006.01)

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FIG.1

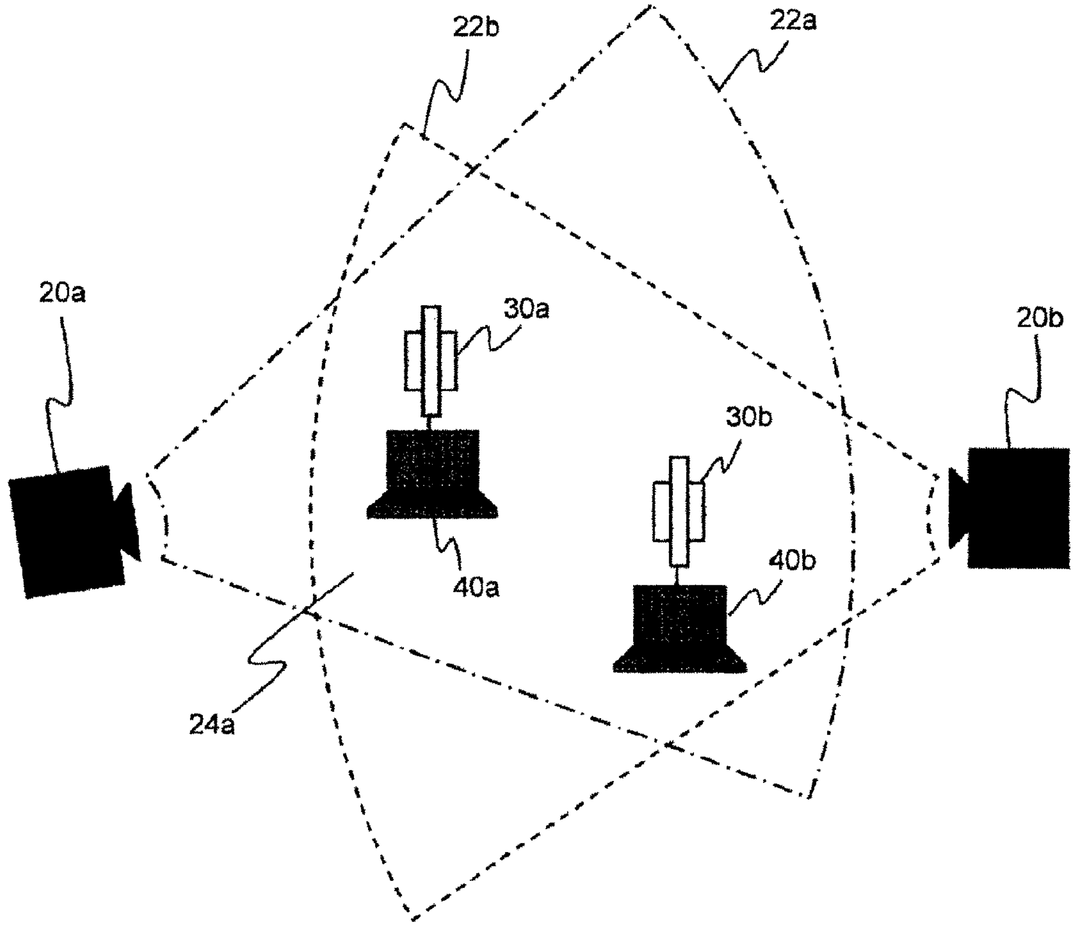


FIG.2

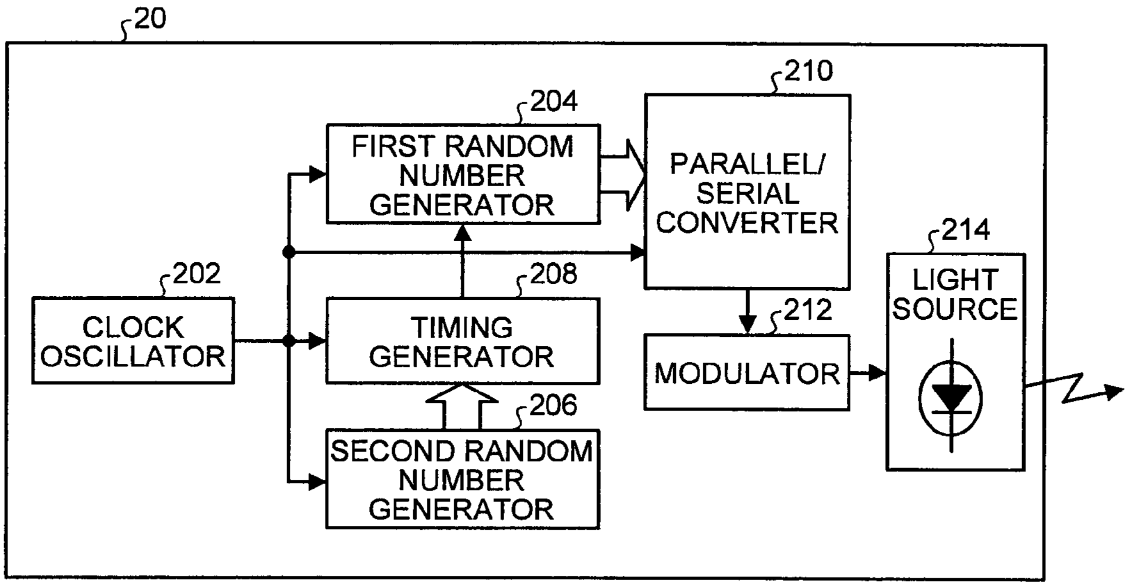

20
204
FIRST RANDOM NUMBER GENERATOR
210
PARALLEL/ SERIAL CONVERTER
214
LIGHT SOURCE
202
CLOCK OSCILLATOR
208
TIMING GENERATOR
212
MODULATOR
206
SECOND RANDOM NUMBER GENERATOR

FIG.3

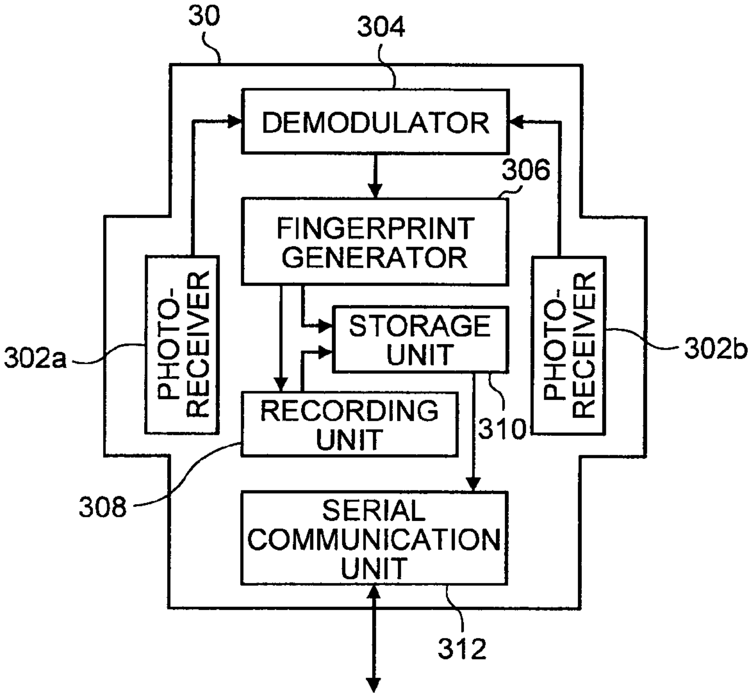

30
304
DEMODULATOR
306
FINGERPRINT GENERATOR
STORAGE UNIT
302a
PHOTO-RECEIVER
PHOTO-RECEIVER
302b
RECORDING UNIT
310
308
SERIAL COMMUNICATION UNIT
312

FIG.4

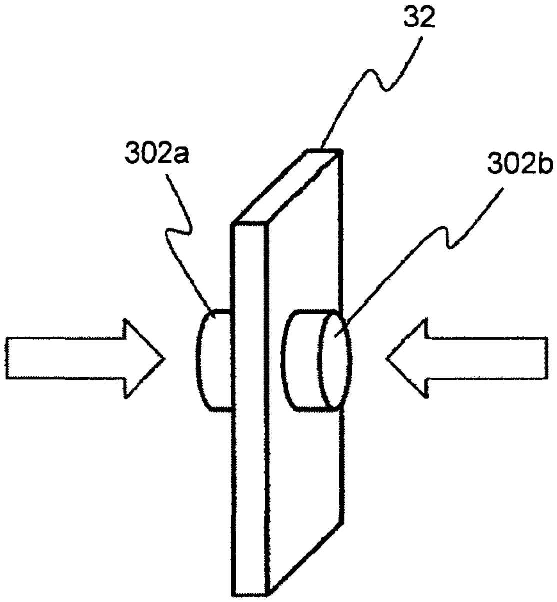

32
302a
302b

FIG.5

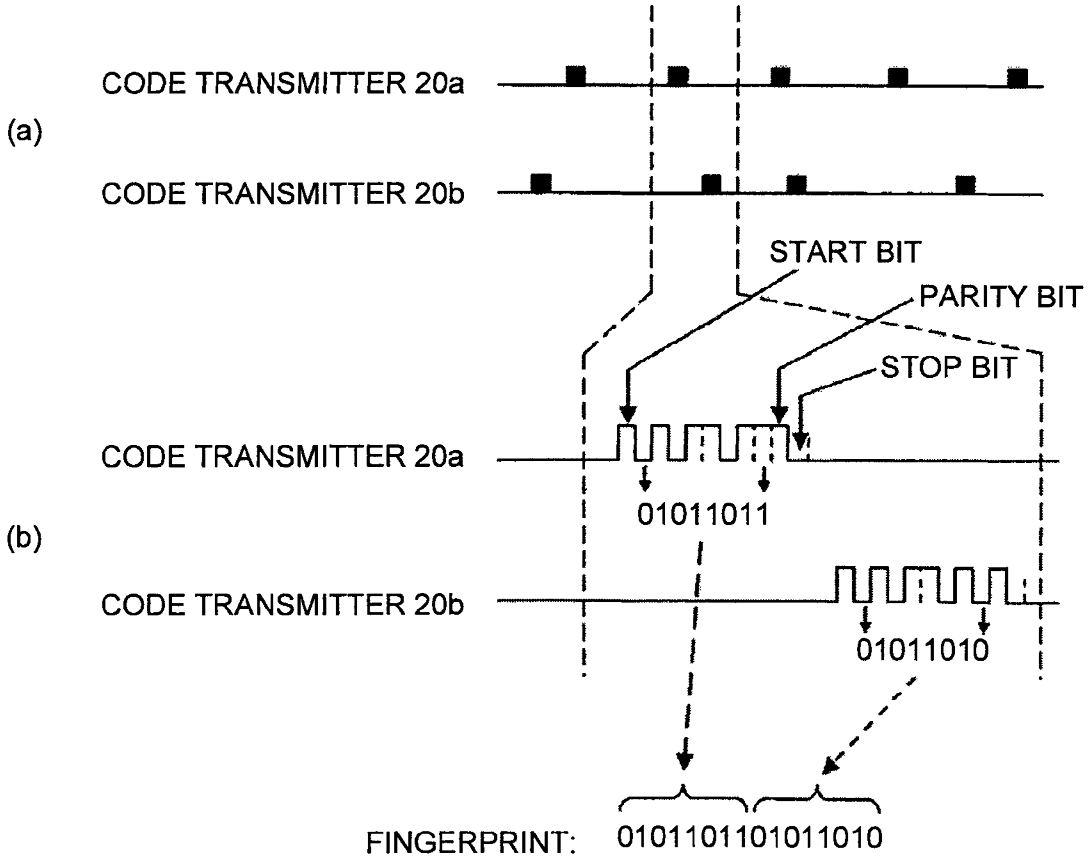

CODE TRANSMITTER 20a
(a)
CODE TRANSMITTER 20b
START BIT
PARITY BIT
STOP BIT
CODE TRANSMITTER 20a
01011011
(b)
CODE TRANSMITTER 20b
01011010
FINGERPRINT:
0101101101011010

FIG.6

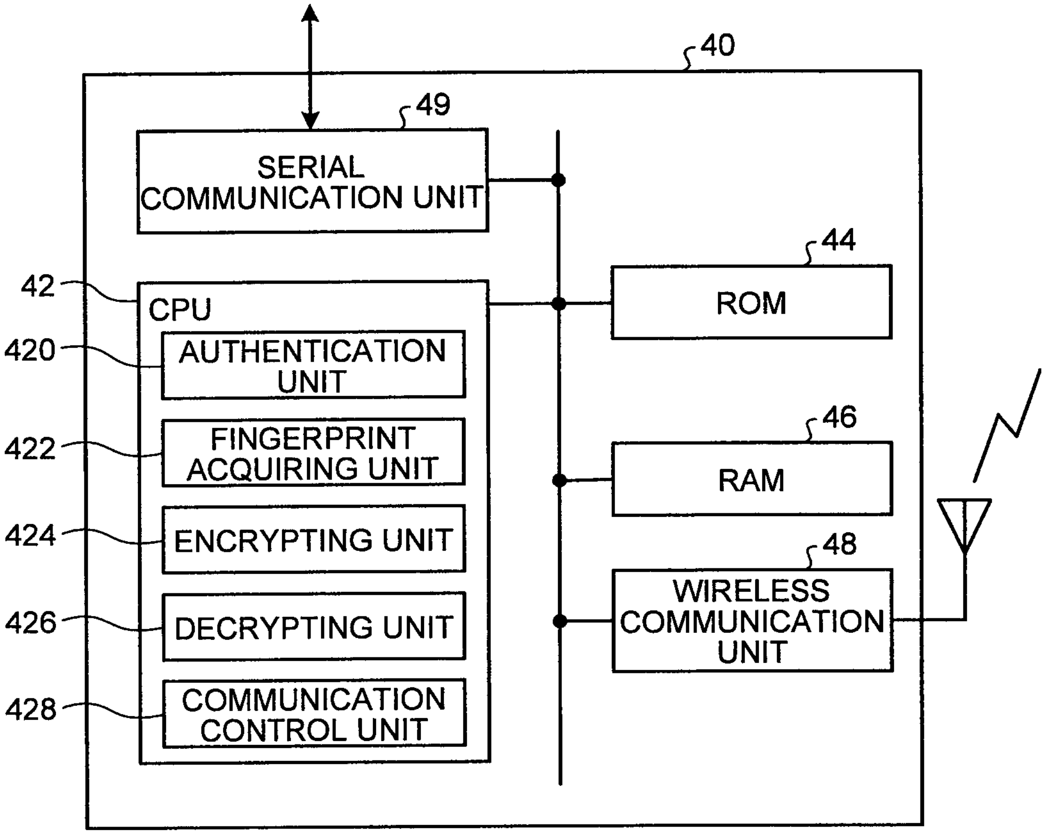

40
49
SERIAL COMMUNICATION UNIT
44
ROM
42
CPU
420
AUTHENTICATION UNIT
422
FINGERPRINT ACQUIRING UNIT
424
ENCRYPTING UNIT
426
DECRYPTING UNIT
428
COMMUNICATION CONTROL UNIT
46
RAM
48
WIRELESS COMMUNICATION UNIT

FIG.7

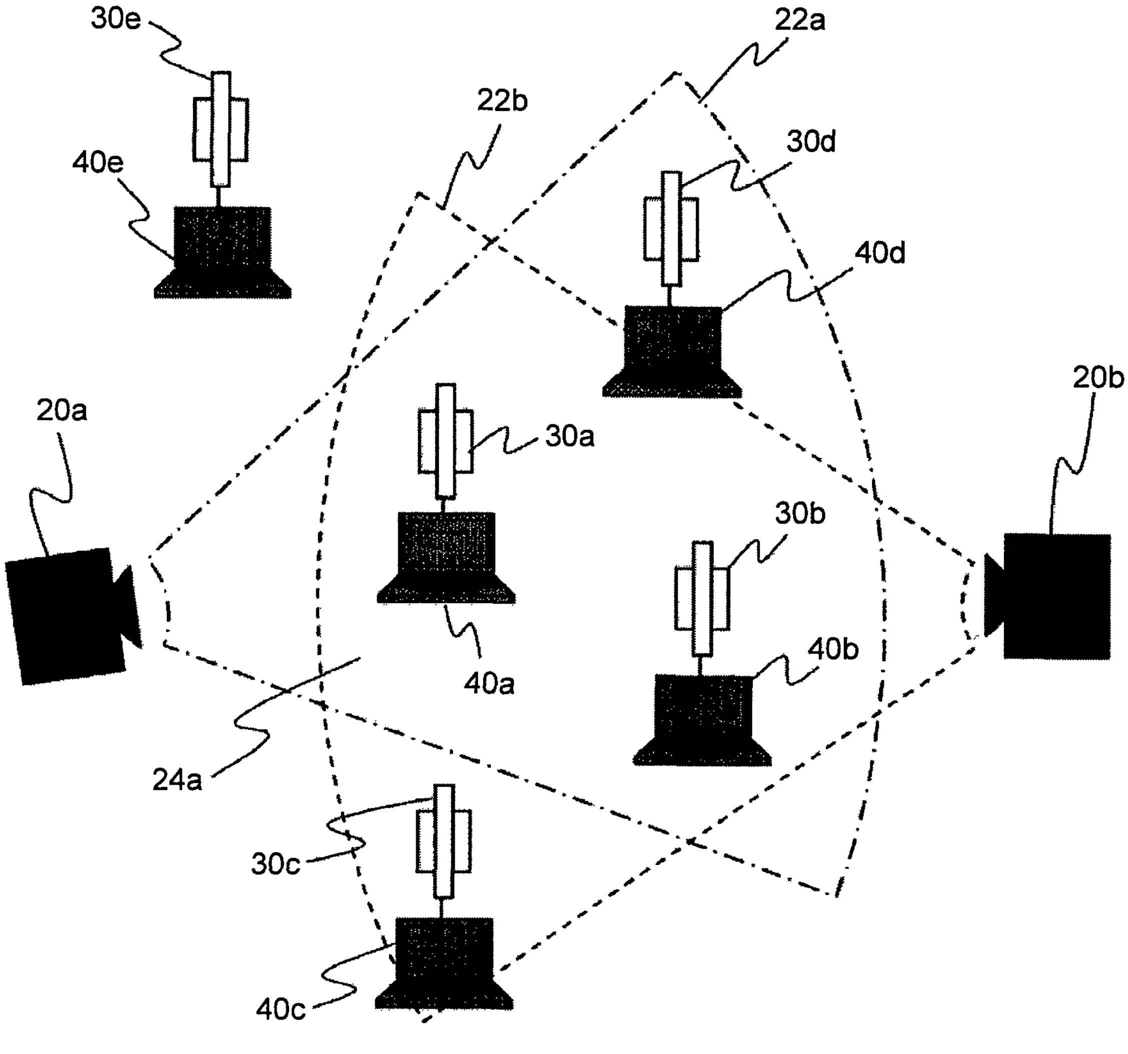


FIG.8

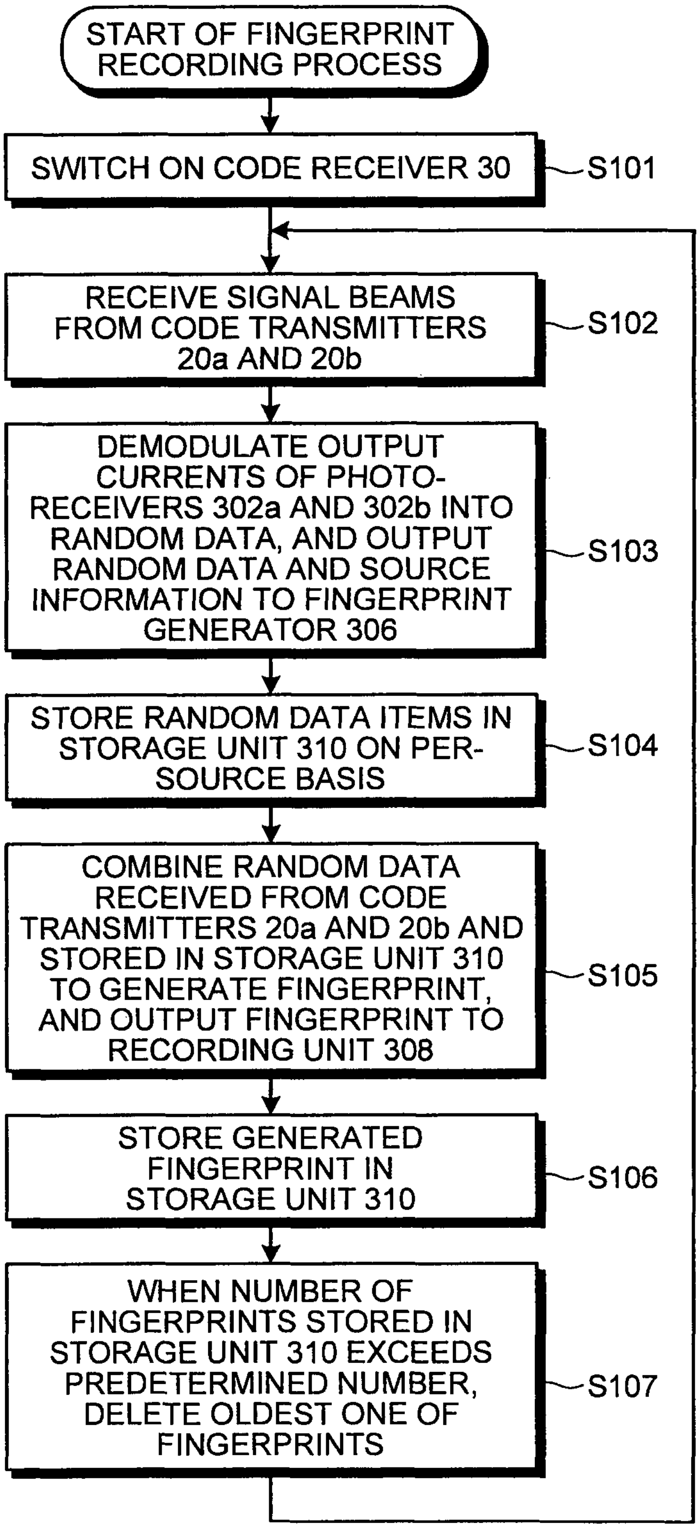

START OF FINGERPRINT RECORDING PROCESS
SWITCH ON CODE RECEIVER 30
S101
RECEIVE SIGNAL BEAMS FROM CODE TRANSMITTERS 20a AND 20b
S102
DEMODULATE OUTPUT CURRENTS OF PHOTO-RECEIVERS 302a AND 302b INTO RANDOM DATA, AND OUTPUT RANDOM DATA AND SOURCE INFORMATION TO FINGERPRINT GENERATOR 306
S103
STORE RANDOM DATA ITEMS IN STORAGE UNIT 310 ON PER-SOURCE BASIS
S104
COMBINE RANDOM DATA RECEIVED FROM CODE TRANSMITTERS 20a AND 20b AND STORED IN STORAGE UNIT 310 TO GENERATE FINGERPRINT, AND OUTPUT FINGERPRINT TO RECORDING UNIT 308
S105
STORE GENERATED FINGERPRINT IN STORAGE UNIT 310
S106
WHEN NUMBER OF FINGERPRINTS STORED IN STORAGE UNIT 310 EXCEEDS PREDETERMINED NUMBER, DELETE OLDEST ONE OF FINGERPRINTS
S107

FIG.9

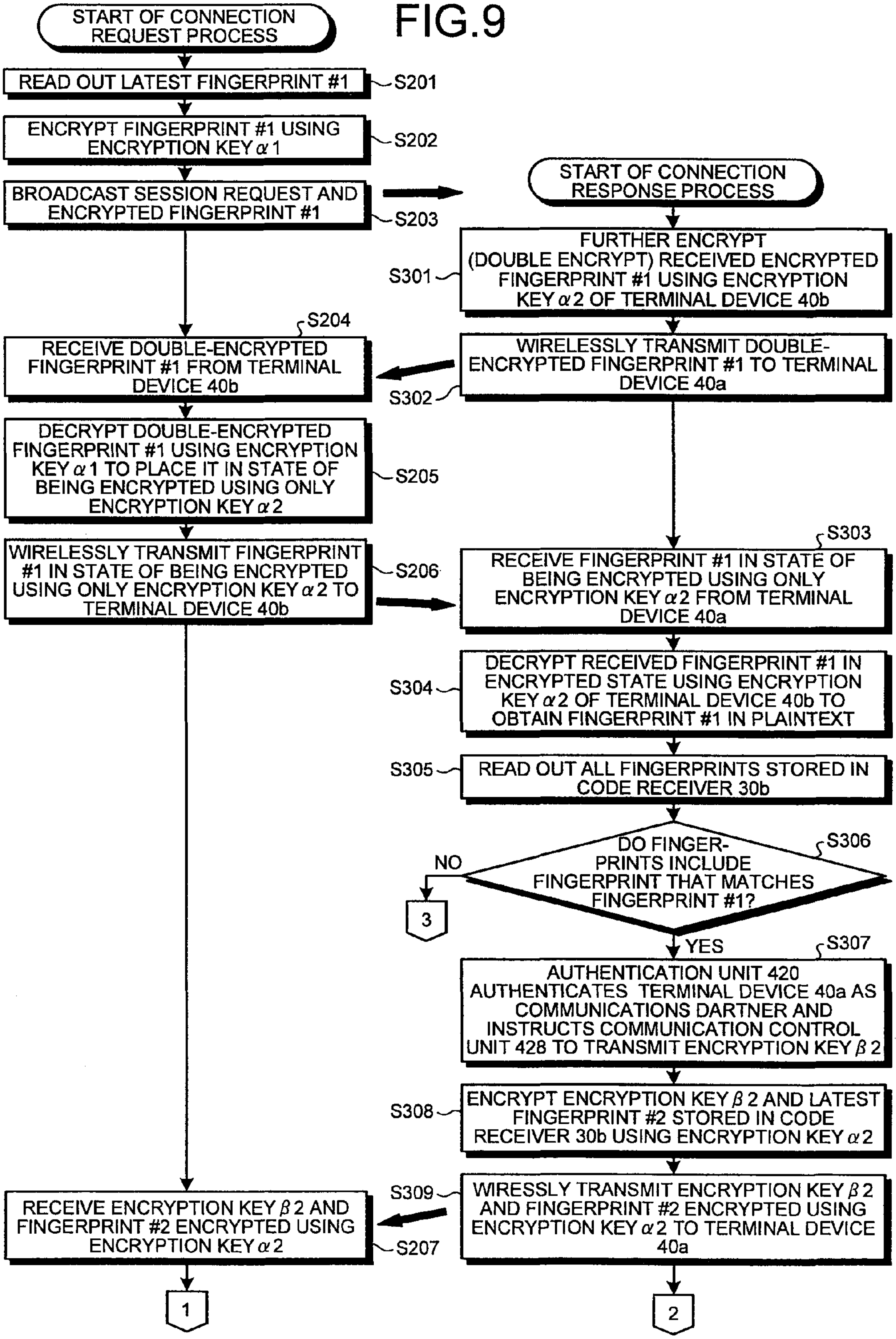

START OF CONNECTION REQUEST PROCESS
READ OUT LATEST FINGERPRINT #1
S201
ENCRYPT FINGERPRINT #1 USING ENCRYPTION KEY α1
S202
BROADCAST SESSION REQUEST AND ENCRYPTED FINGERPRINT #1
S203
START OF CONNECTION RESPONSE PROCESS
FURTHER ENCRYPT (DOUBLE ENCRYPT) RECEIVED ENCRYPTED FINGERPRINT #1 USING ENCRYPTION KEY α2 OF TERMINAL DEVICE 40b
S301
S204
RECEIVE DOUBLE-ENCRYPTED FINGERPRINT #1 FROM TERMINAL DEVICE 40b
WIRELESSLY TRANSMIT DOUBLE-ENCRYPTED FINGERPRINT #1 TO TERMINAL DEVICE 40a
S302
DECRYPT DOUBLE-ENCRYPTED FINGERPRINT #1 USING ENCRYPTION KEY α1 TO PLACE IT IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α2
S205
S303
WIRELESSLY TRANSMIT FINGERPRINT #1 IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α2 TO TERMINAL DEVICE 40b
S206
RECEIVE FINGERPRINT #1 IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α2 FROM TERMINAL DEVICE 40a
S304
DECRYPT RECEIVED FINGERPRINT #1 IN ENCRYPTED STATE USING ENCRYPTION KEY α2 OF TERMINAL DEVICE 40b TO OBTAIN FINGERPRINT #1 IN PLAINTEXT
S305
READ OUT ALL FINGERPRINTS STORED IN CODE RECEIVER 30b
DO FINGER-PRINTS INCLUDE FINGERPRINT THAT MATCHES FINGERPRINT #1?
S306
NO
3
YES
S307
AUTHENTICATION UNIT 420 AUTHENTICATES TERMINAL DEVICE 40a AS COMMUNICATIONS DARTNER AND INSTRUCTS COMMUNICATION CONTROL UNIT 428 TO TRANSMIT ENCRYPTION KEY β2
S308
ENCRYPT ENCRYPTION KEY β2 AND LATEST FINGERPRINT #2 STORED IN CODE RECEIVER 30b USING ENCRYPTION KEY α2
S309
RECEIVE ENCRYPTION KEY β2 AND FINGERPRINT #2 ENCRYPTED USING ENCRYPTION KEY α2
WIRESSLY TRANSMIT ENCRYPTION KEY β2 AND FINGERPRINT #2 ENCRYPTED USING ENCRYPTION KEY α2 TO TERMINAL DEVICE 40a
S207
1
2

FIG.10

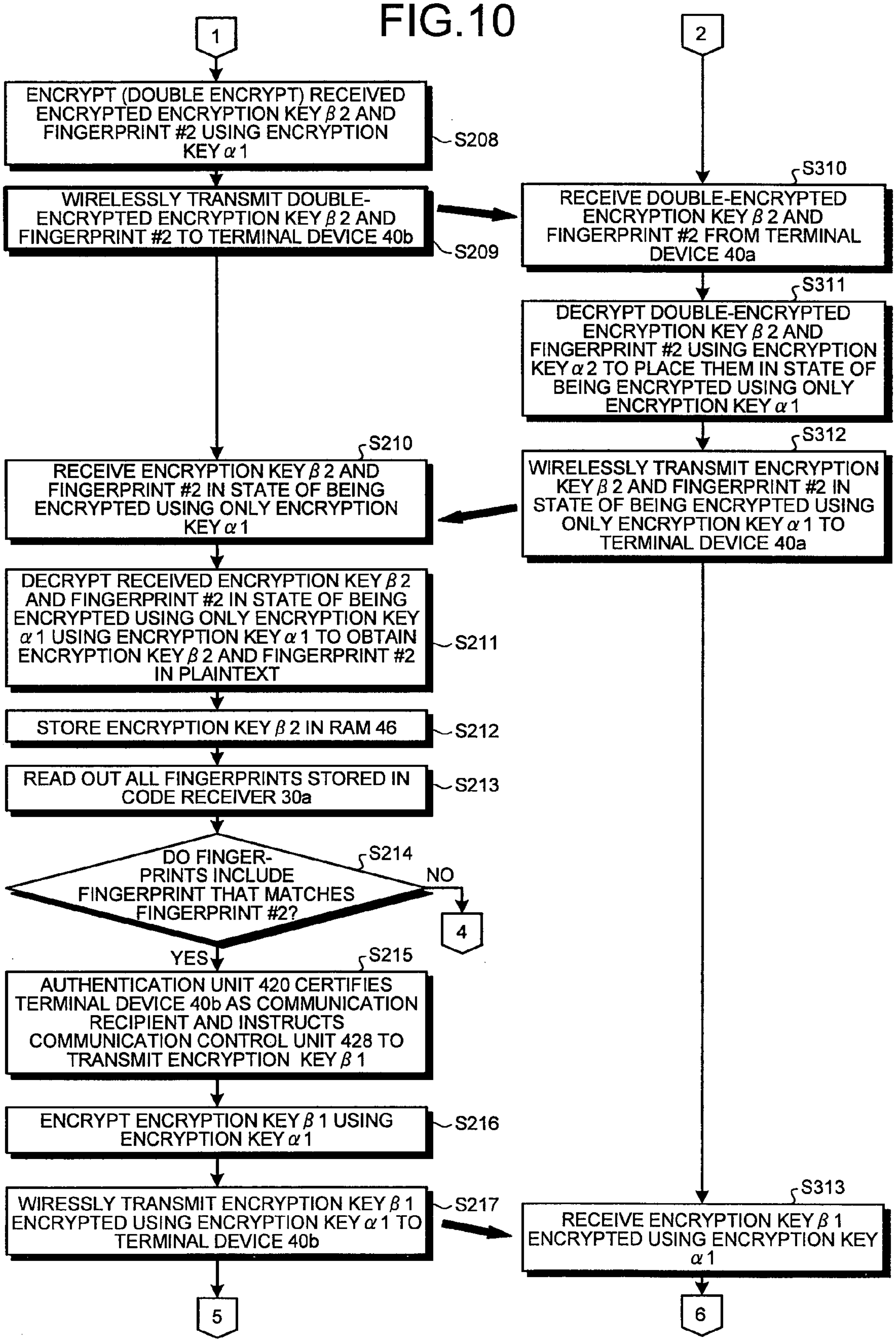

1
2
ENCRYPT (DOUBLE ENCRYPT) RECEIVED ENCRYPTED ENCRYPTION KEY β 2 AND FINGERPRINT #2 USING ENCRYPTION KEY α 1
S208
WIRELESSLY TRANSMIT DOUBLE-ENCRYPTED ENCRYPTION KEY β 2 AND FINGERPRINT #2 TO TERMINAL DEVICE 40b
S209
S310
RECEIVE DOUBLE-ENCRYPTED ENCRYPTION KEY β 2 AND FINGERPRINT #2 FROM TERMINAL DEVICE 40a
S311
DECRYPT DOUBLE-ENCRYPTED ENCRYPTION KEY β 2 AND FINGERPRINT #2 USING ENCRYPTION KEY α 2 TO PLACE THEM IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α 1
S312
WIRELESSLY TRANSMIT ENCRYPTION KEY β 2 AND FINGERPRINT #2 IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α 1 TO TERMINAL DEVICE 40a
S210
RECEIVE ENCRYPTION KEY β 2 AND FINGERPRINT #2 IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α 1
DECRYPT RECEIVED ENCRYPTION KEY β 2 AND FINGERPRINT #2 IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α 1 USING ENCRYPTION KEY α 1 TO OBTAIN ENCRYPTION KEY β 2 AND FINGERPRINT #2 IN PLAINTEXT
S211
STORE ENCRYPTION KEY β 2 IN RAM 46
S212
READ OUT ALL FINGERPRINTS STORED IN CODE RECEIVER 30a
S213
DO FINGER-PRINTS INCLUDE FINGERPRINT THAT MATCHES FINGERPRINT #2?
S214
NO
4
YES
S215
AUTHENTICATION UNIT 420 CERTIFIES TERMINAL DEVICE 40b AS COMMUNICATION RECIPIENT AND INSTRUCTS COMMUNICATION CONTROL UNIT 428 TO TRANSMIT ENCRYPTION KEY β 1
ENCRYPT ENCRYPTION KEY β 1 USING ENCRYPTION KEY α 1
S216
WIRESSLY TRANSMIT ENCRYPTION KEY β 1 ENCRYPTED USING ENCRYPTION KEY α 1 TO TERMINAL DEVICE 40b
S217
S313
RECEIVE ENCRYPTION KEY β 1 ENCRYPTED USING ENCRYPTION KEY α 1
5
6

FIG.11

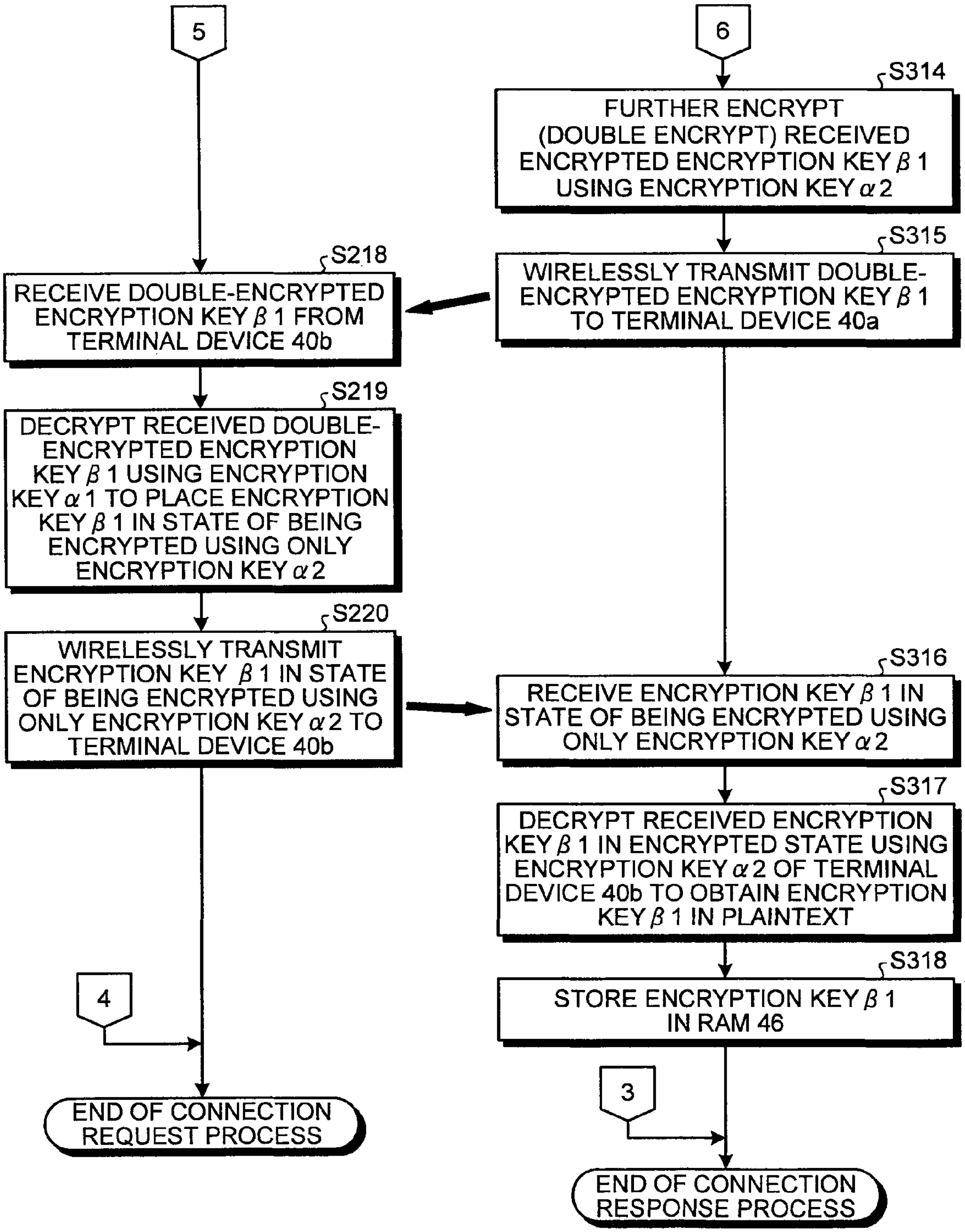

5
6
S314
FURTHER ENCRYPT (DOUBLE ENCRYPT) RECEIVED ENCRYPTED ENCRYPTION KEY β1 USING ENCRYPTION KEY α2
S315
WIRELESSLY TRANSMIT DOUBLE-ENCRYPTED ENCRYPTION KEY β1 TO TERMINAL DEVICE 40a
S218
RECEIVE DOUBLE-ENCRYPTED ENCRYPTION KEY β1 FROM TERMINAL DEVICE 40b
S219
DECRYPT RECEIVED DOUBLE-ENCRYPTED ENCRYPTION KEY β1 USING ENCRYPTION KEY α1 TO PLACE ENCRYPTION KEY β1 IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α2
S220
WIRELESSLY TRANSMIT ENCRYPTION KEY β1 IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α2 TO TERMINAL DEVICE 40b
S316
RECEIVE ENCRYPTION KEY β1 IN STATE OF BEING ENCRYPTED USING ONLY ENCRYPTION KEY α2
S317
DECRYPT RECEIVED ENCRYPTION KEY β1 IN ENCRYPTED STATE USING ENCRYPTION KEY α2 OF TERMINAL DEVICE 40b TO OBTAIN ENCRYPTION KEY β1 IN PLAINTEXT
S318
STORE ENCRYPTION KEY β1 IN RAM 46
4
END OF CONNECTION REQUEST PROCESS
3
END OF CONNECTION RESPONSE PROCESS

FIG.12A

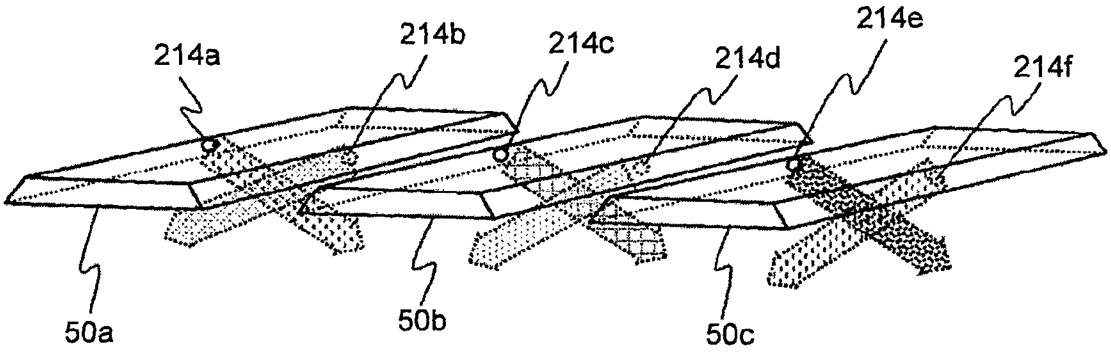


FIG.12B

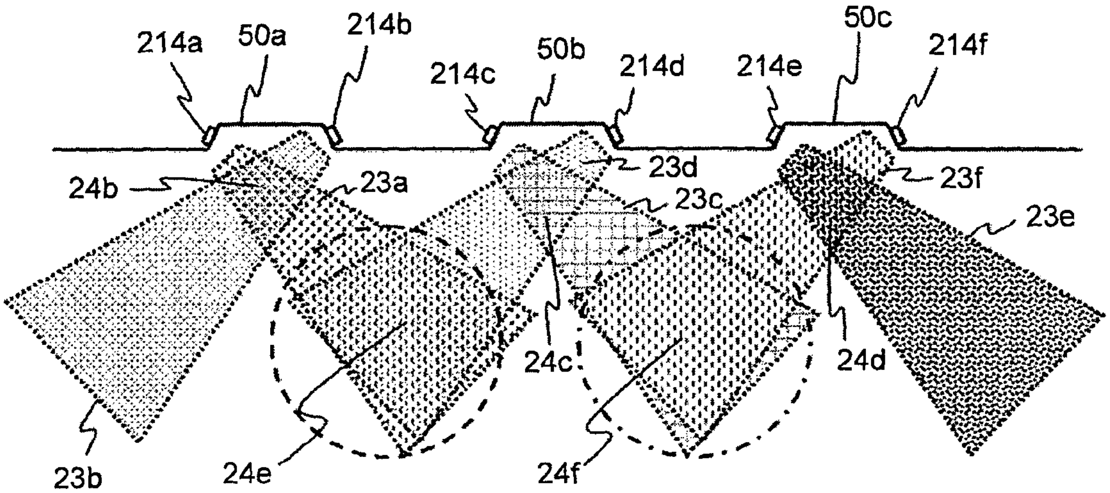


FIG.13

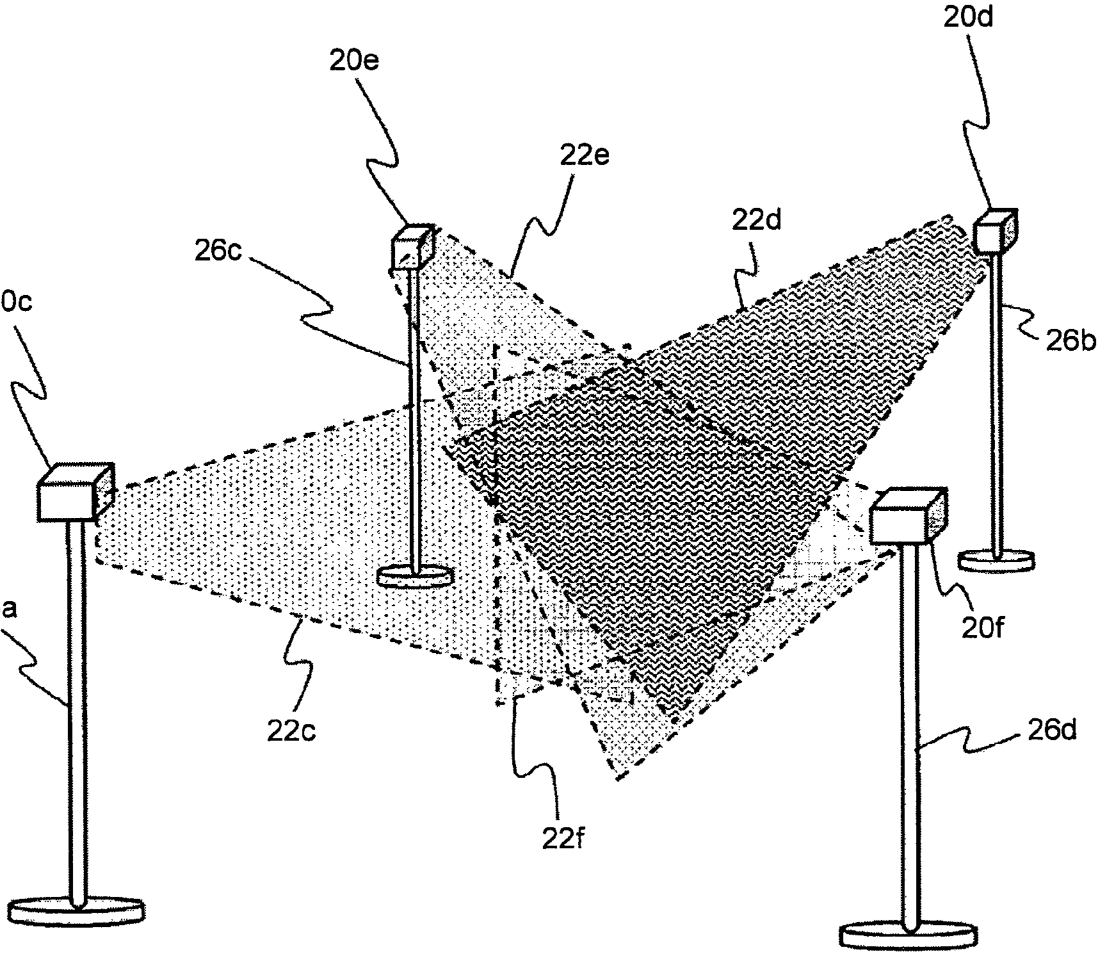


FIG.14

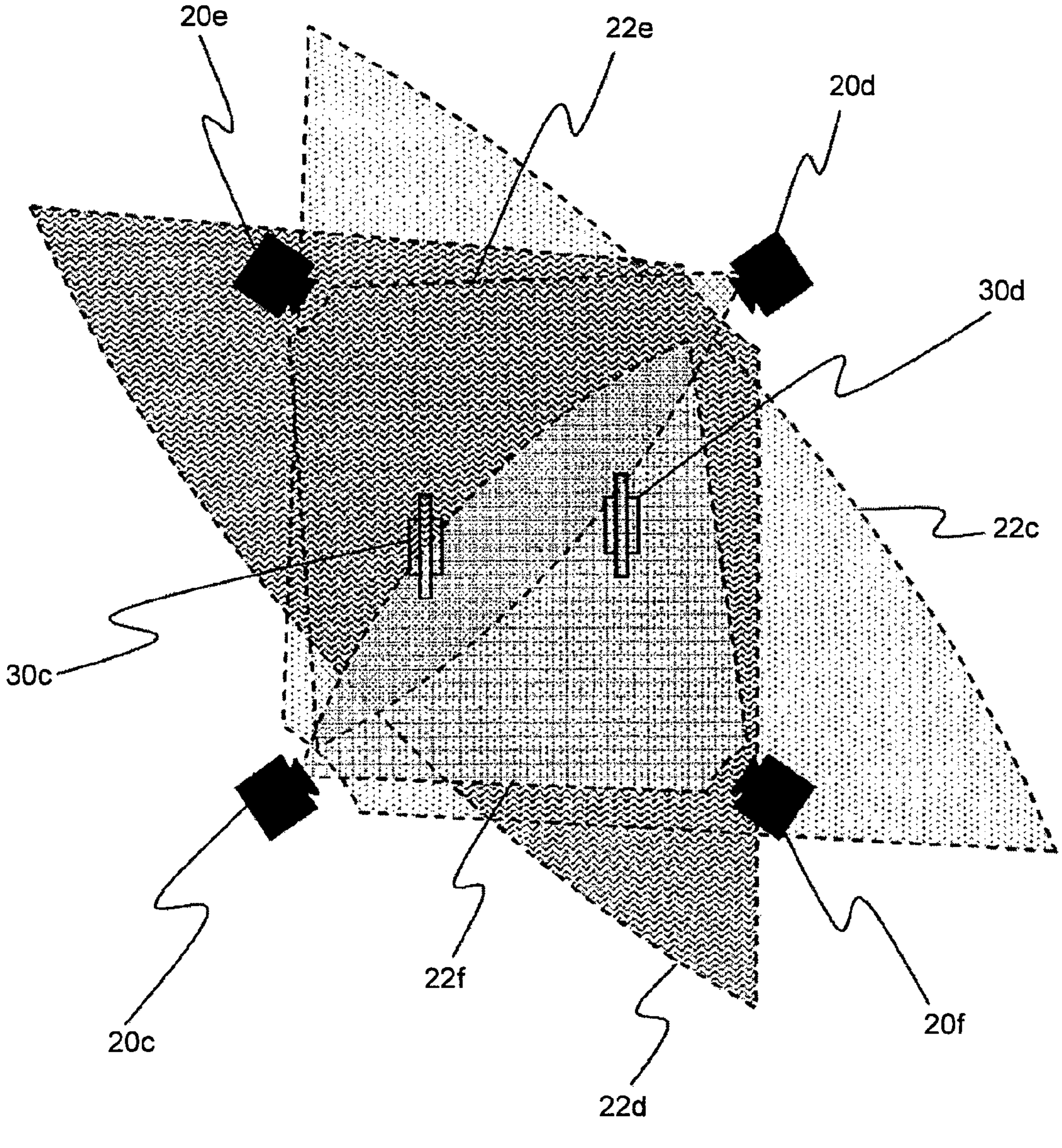


FIG.15

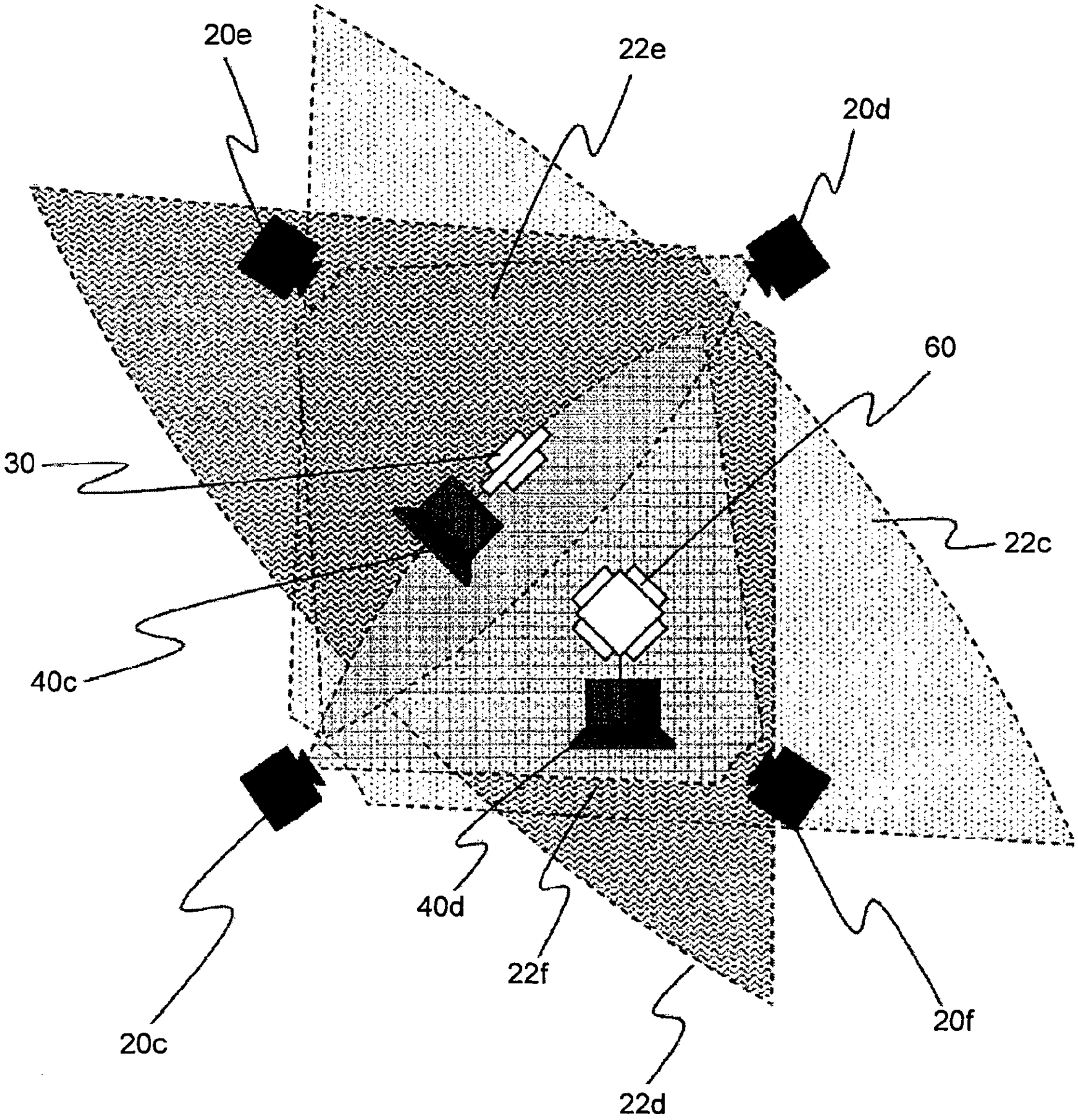


FIG.16

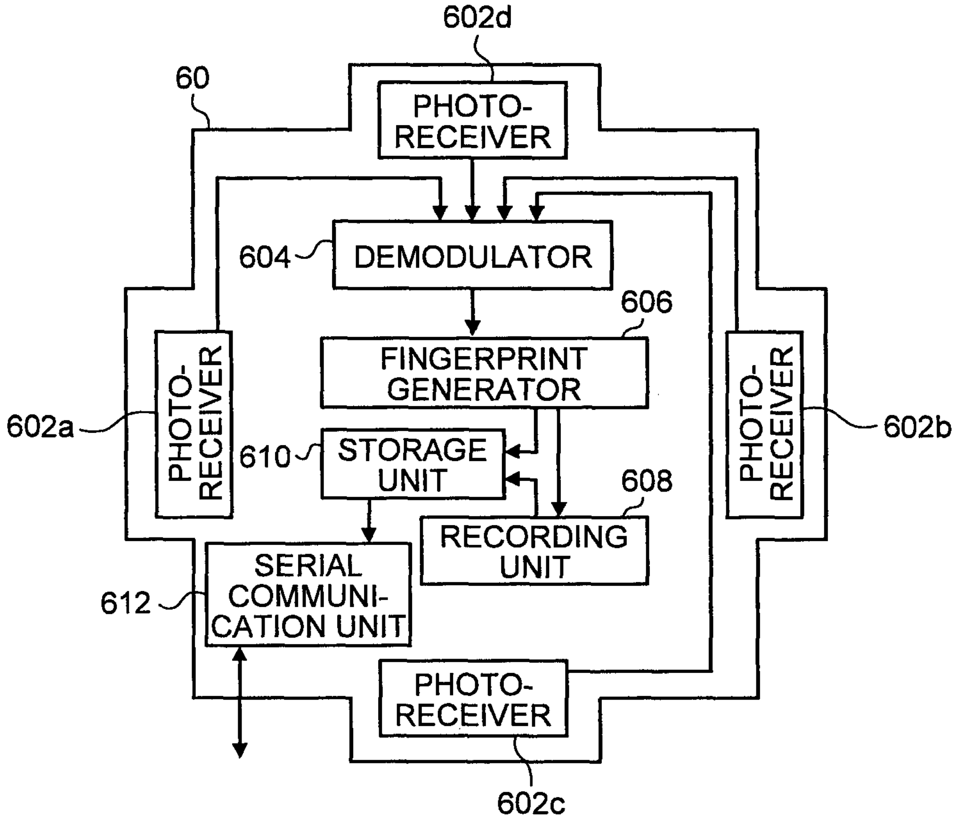
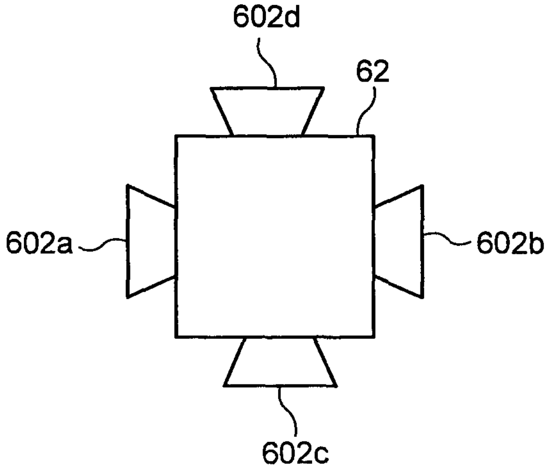

602d
60
PHOTO-RECEIVER
604
DEMODULATOR
606
FINGERPRINT GENERATOR
602a
PHOTO-RECEIVER
610
STORAGE UNIT
608
RECORDING UNIT
PHOTO-RECEIVER
602b
612
SERIAL COMMUNI-CATION UNIT
PHOTO-RECEIVER
602c

FIG.17


602d
62
602a
602b
602c

WIRELESS COMMUNICATION SYSTEM AND TERMINAL-DEVICE AUTHENTICATION METHOD IN WIRELESS COMMUNICATION SYSTEM

TECHNICAL FIELD

The present invention relates to a wireless communication system and a terminal-device authentication method in the wireless communication system.

BACKGROUND ART

Terminal devices connectable to a wired or wireless LAN (Local Area Network) are growing in number and convenience of information exchange has been greatly improved as information and communication technology (ICT) infrastructure is being deployed. As communication standards for such LANs, the IEEE 802.3 standard for wired LANs and the IEEE 802.11 standard for wireless LANs are widely used.

The IEEE 802.11 standard incorporates network management methods, such as a terminal-device authentication method, of the IEEE 802.3 standard for wired LANs. Constructing a wireless LAN in accordance with the IEEE 802.11 standard allows settings of terminal devices to be made through similar processes at transition from a wired LAN to a wireless LAN or for combined use of a wired LAN and a wireless LAN. However, convenience native to wireless communication is impaired in some cases as a result of incorporating the management methods for wired LANs into a wireless LAN.

For example, the IEEE 802.11 standard requires that cumbersome authentication steps should be performed when connecting a terminal device to a network to determine authenticity of the terminal device and the like as does the IEEE 802.3 standard.

Meanwhile, wireless technologies are also widely used in interfaces, such as projectors and displays, for example, for one-to-one connection to a personal computer (PC). A security function similar to that for network connection, namely, a security function requirement set by the IEEE 802.11 standard, is also inherited to authentication for such connection.

Such one-to-one interface connection is in many cases temporary connection used only during a period of meeting, for example, and it is clearly undesirable that many cumbersome steps are required to establish the connection or to change a terminal device to be connected.

The same holds true to temporary connections between a plurality of terminal devices in a confined area in such a circumstance, which is arising more frequently as variety of electronic information increases, where terminal devices such as PCs are brought into a meeting room or the like to share a file.

A possible solution for this problem is personal area network (PAN) such as Bluetooth (registered trademark) that performs terminal-device authentication by causing terminal devices to exchange an authentication code which is called a personal identification number (PIN) code or a passcode.

Known examples of a wireless communication terminal device that uses Bluetooth (registered trademark) described above include a wireless communication terminal device in which an equipment list containing equipment IDs, profile types (types of equipment), and positional information about installation locations of other wireless communication terminal devices (e.g., equipment present in an office) on a per-wireless-communication-terminal-device basis is stored in advance. In response to user's selection of a wireless communication terminal device at a desired installation location, for example, from the equipment list displayed on each of the wireless communication terminal devices, wireless communication connection is established between a wireless communication terminal device of the user and the selected wireless communication terminal device (see Japanese Patent Application Laid-open No. 2002-290416, for example).

However, the wireless communication terminal device described in Japanese Patent Application Laid-open No. 2002-290416 premises that the positional information is stored in the equipment list in advance. Accordingly, when the wireless communication terminal has been relocated from its installation location, the positional information in the equipment list becomes useless. For this reason, with the conventional wireless communication terminal device described above, a communications partner cannot be selected appropriately from the equipment list in such an application where temporary communication connection is carried out between wireless communication terminal devices moved into a meeting room or the like.

Furthermore, in a PAN such as Bluetooth (registered trademark), a connection range is indefinite because means that explicitly specifies a connectable physical range (e.g., within a meeting room, at distances up to 10 meters, or the like) is not provided, and it is necessary to perform an authentication process, such as exchange of a PIN code, for ensuring a security function similar to that of network communication for identification of a target object which is a connection target. Accordingly, connection cannot be established easily.

Thus, authentication and communication establishing means convenient and suited for circumstances where temporary connection between terminal devices in a predetermined area, such as a meeting room, for example, is desirable is not provided yet.

Therefore, there is a need for a system capable of establishing communication connection in wireless communication in a temporarily-used area, such as a meeting room, by performing authentication of terminal devices easily and quickly by utilizing a fact that the terminal devices are at a same place at same time.

DISCLOSURE OF INVENTION

It is an object of the present invention to at least partially solve the problems in the conventional technology.

According to an embodiment, there is provided a wireless communication system that includes a plurality of code transmitters each configured to transmit a time-varying code, the time-varying codes transmitted from the code transmitters being different from each other; a plurality of code receivers each configured to receive the time-varying codes transmitted from the code transmitters and generate a fingerprint based on the received time-varying codes, the fingerprint being unique to a space where the time-varying codes are receivable; and a plurality of terminal devices configured to establish wireless communication connection therebetween with authentication, the terminal devices being connected to the code receivers, respectively. Each of the terminal devices includes a fingerprint acquiring unit configured to acquire the fingerprint from the code receiver connected thereto, a wireless communication unit configured to transmit and receive the fingerprint via wireless communication, and an authentication unit configured to authenticate, as a communications partner, another one of the terminal devices if the fingerprint received by the wireless communication unit from the another one of the terminal devices matches the fingerprint acquired by the fingerprint acquiring unit from the code receiver connected thereto.

According to another embodiment, there is provided a terminal-device authentication method in a wireless communication system including a plurality of terminal devices configured to establish wireless communication connection therebetween with authentication. The terminal-device authentication method includes transmitting, by each of the code transmitters, a time-varying code, the time-varying codes transmitted from the code transmitters being different from each other; receiving, by a plurality of code receivers connected to the terminal devices respectively, the time-varying codes transmitted from the code transmitters; generating, by each of the code receivers, a fingerprint based on the received time-varying codes, the fingerprint being unique to a space where the time-varying codes are receivable; acquiring, by each of the terminal devices, the fingerprint from the code receiver connected thereto; transmitting, by each of the terminal devices, the fingerprint via wireless communication; receiving, by each of the terminal devices, the fingerprint via the wireless communication; and authenticating, as a communications partner of one of the terminal devices, another one of the terminal devices if the fingerprint received from the another one of the terminal devices matches the fingerprint acquired by the one of the terminal devices.

The above and other objects, features, advantages and technical and industrial significance of this invention will be better understood by reading the following detailed description of presently preferred embodiments of the invention, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram illustrating a configuration of a wireless communication system according to a first embodiment;

FIG. **2** is a block diagram illustrating a configuration of a code transmitter;

FIG. **3** is a block diagram illustrating a configuration of a code receiver;

FIG. **4** is a diagram illustrating an example of arrangement of photo-receivers;

FIG. **5** illustrates an example of pieces of random data and a fingerprint;

FIG. **6** is a block diagram illustrating a configuration of a terminal device;

FIG. **7** is a diagram illustrating another example of arrangement of terminal devices;

FIG. **8** is a flowchart illustrating a procedure for a fingerprint recording process;

FIG. **9** is a flowchart illustrating a procedure for a communication connection process;

FIG. **10** is a flowchart illustrating the procedure for the communication connection process;

FIG. **11** is a flowchart illustrating the procedure for the communication connection process;

FIG. **12**A illustrates an example of installation of code transmitters according to a second embodiment;

FIG. **12**B illustrates the example of installation of code transmitters according to the second embodiment;

FIG. **13** is a diagram illustrating an example of installation of code transmitters according to a third embodiment;

FIG. **14** is a diagram illustrating an example of arrangement of code receivers according to the third embodiment;

FIG. **15** is a diagram illustrating a configuration of a wireless communication system according to a fourth embodiment;

FIG. **16** is a block diagram illustrating a configuration of a code receiver according to the fourth embodiment; and

FIG. **17** is a diagram illustrating an example of arrangement of photo-receivers according to the fourth embodiment.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

A first embodiment of the present invention is described below with reference to the drawings.

The wireless communication system according to the present embodiment includes two code transmitters each transmitting a piece of random data as time-varying codes by emitting modulated signal beams at a predetermined beam angle, code receivers which are placed in an area where the beams emitted from the two code transmitters intersect and each of which receives the pieces of random data from the two code transmitters to generate a fingerprint based on the received two pieces of random data (for example, by combining these pieces of random data), and terminal devices respectively connected to the code receivers. Each of the terminal devices obtains the fingerprint from the code receiver connected to the terminal device, transmits the obtained fingerprint to and receives the obtained fingerprint from another terminal device by wireless communication, authenticates, as a communications partner, the another terminal device that has transmitted the same fingerprint as that of the terminal device, and establishes wireless communication connection therewith.

In this specification, the fingerprint is defined as information that allows observers to determine that the observers are present at a same place at same time and that is unique to the time and the place.

FIG. **1** is a block diagram illustrating a configuration of the wireless communication system according to the first embodiment of the present invention.

The wireless communication system includes two code transmitters **20***a* and **20***b*, code receivers **30***a* and **30***b* that each receive beams emitted from the code transmitters **20***a* and **20***b*, and terminal devices **40***a* and **40***b*, which are personal computers (PCs) or the like connected to the code receivers **30***a* and **30***b*, respectively. Connection between the code receiver **30***a* and the terminal device **40***a* and connection between the code receiver **30***a* and the terminal device **40***b* can be made via a serial bus such as Universal Serial Bus (USB), RS232C, or the like. The code receivers **30***a* and **30***b* are arranged in an area **24***a* where an illumination area **22***a* of the beam emitted from the code transmitter **20***a* and an illumination area **22***b* of the beam emitted from code transmitter **20***b* intersect.

Meanwhile, the code transmitters **20***a* and **20***b* are identical in configuration; the code receivers **30***a* and **30***b* are identical in configuration; the terminal devices **40***a* and **40***b* are identical in configuration. Accordingly, in the following description, each of them is referred to as "the code transmitter **20**" or such without a corresponding suffix when collectively referred to, while each of them is referred to as "the code transmitter **20***a*" or such with the corresponding suffix when individually referred to.

The configuration of the code transmitter **20** is described below first.

FIG. **2** is a block diagram illustrating a configuration the code transmitter **20**.

The code transmitter **20** includes a clock oscillator **202** that generates a clock signal of a predetermined cycle, first and second random number generators **204** and **206**, a timing generator **208**, a parallel/serial converter **210**, a modulator **212**, and a light source **214**. Each of the random number generators **204** and **206** can be formed of a pseudorandom number generator that generates a predetermined sequence of pseudorandom numbers.

The second random number generator **206** generates a random number when the clock signal goes high, for example, and outputs the generated random number to the timing generator **208**.

When the random number output by the second random number generator **206** satisfies a predetermined condition, the timing generator **208** outputs an output command signal that directs the first random number generator **204** to output the random number generated inside the first random number generator **204**. The predetermined condition is, for example, that the random number output by the second random number generator **206** is within a predetermined range of values or that the random number is a multiple of a predetermined value.

The first random number generator **204** generates a random number when the clock signal goes high, for example, and outputs the generated random number to the timing generator **208**, and, upon receiving the output command signal from the timing generator **208**, outputs the generated random number to the parallel/serial converter **210** in a form of 8-bit parallel data, for example.

The parallel/serial converter **210** converts the 8-bit parallel data output from the first random number generator **204** into serial data in synchronization with the clock signal and outputs the serial data to the modulator **212**.

The modulator **212** modulates intensity of a beam emitted from the light source **214** according to the 8-bit serial data output by the parallel/serial converter **210** by controlling a driving current of the light source **214**. With regard to modulation, asynchronous communication signals can be obtained from the serial data in such a manner that a start bit is inserted before the 8-bit serial data and a parity bit and a stop bit are inserted after the 8-bit serial data.

The light source **214** emits a beam that diverges at a predetermined beam angle. Accordingly, the single area (**24***a* of FIG. **1**) can be formed by causing the beams emitted from the two code transmitters **20***a* and **20***b* to intersect.

The light source **214** is driven by the modulator **212** to transmit the serial data (random data) based on the random number generated by the first random number generator **204** as an intensity-modulated beam. A light emitting diode (LED) that emits visible light or invisible light (e.g., infrared light) or the like can be used as the light source **214**.

The code transmitter **20** configured as described above generates the random data that is the time-varying code based on the random number generated by the first random number generator **204** and transmits the random data by emitting the beam modulated with the random data from the light source **214**.

The configuration of the code receiver **30** is described next. FIG. **3** is a block diagram illustrating the configuration of the code receiver **30**.

The code receiver **30** includes photo-receivers **302***a* and **302***b*, a demodulator **304**, a fingerprint generator **306**, a recording unit **308**, a storage unit **310** made up of a RAM or the like, and a serial communication unit **312**.

The photo-receivers **302***a* and **302***b* receive the intensity-modulated beams, which are the beams emitted from the code transmitters **20***a* and **20***b*, respectively, and convert the beams into electric signals (intensity-modulation signals). Photodiodes, phototransistors, or the like suited for an emission wavelength of the light source **214** of the code transmitter **20** can be used as the photo-receivers **302***a* and **302***b*. In addition, the photo-receivers **302***a* and **302***b* are configured by being arranged on a front surface and a back surface, respectively, of a substrate **32** so that each of the photo-receivers **302***a* and **302***b* can separately receive one of the beams emitted from the code transmitters **20***a* and **20***b* traveling in two opposing directions. Arrows indicated in FIG. **4** denote a beam emitted from the code transmitter **20***a* and incident on the photo-receiver **302***a* and a beam emitted from the code transmitter **20***b* and incident on the photo-receiver **302***b*.

The demodulator **304** demodulates the electric signals output from the photo-receivers **302***a* and **302***b* and outputs the respective pieces of random data (8-bit data) transmitted from the code transmitters **20***a* and **20***b* accompanied with source information (information indicating from which one of the code transmitters **20***a* and **20***b* is a source of the piece of random data) to the fingerprint generator **306**.

The fingerprint generator **306** stores the pieces of random data output from the demodulator **304** on a per-source basis (namely, for the code transmitter **20***a* and the code transmitter **20***b* separately) in the storage unit **310**. As a result, a latest piece of random data transmitted from the code transmitter **20***a* and a latest piece of random data transmitted from the code transmitter **20***b* are consistently stored in the storage unit **310**. Thereafter, the fingerprint generator **306** combines these two pieces of random data (each 8-bit) stored in the storage unit **310** to generate a fingerprint (16-bit), and outputs the fingerprint to the recording unit **308**.

As a consequence of the operations described above, the fingerprint generator **306** generates a new fingerprint at a point in time where any one of the two pieces of random data transmitted from the code transmitters **20***a* and **20***b* is changed.

Meanwhile, the fingerprint can be any fingerprint so long as the fingerprint is generated based on the two pieces of random data transmitted from the code transmitters **20***a* and **20***b* and not limited to such a fingerprint of the present embodiment obtained by combining the pieces of random data but can be a logical product or a logical sum of the two pieces of random data.

In addition, timing when the fingerprint is to be generated is not limited to the point in time of the present embodiment where any one of the two pieces of random data transmitted from the code transmitters **20***a* and **20***b* is changed, but can be a point in time where both the two pieces of random data transmitted from the code transmitters **20***a* and **20***b* are changed.

Next, the recording unit **308** stores fingerprints generated by the fingerprint generator **306** in the storage unit **310** in an order in which they are generated. In addition, an oldest one of the fingerprints is deleted from the storage unit **310** when the number of the stored fingerprints exceeds a predetermined number, thereby causing the predetermined number of fingerprints to be consistently held in the storage unit **310**.

In addition, the serial communication unit **312** exchanges data with the terminal device **40** via a USB or the like serial bus.

FIG. **5** illustrates an example of the pieces of random data transmitted from the two code transmitters **20***a* and **20***b* and the fingerprint generated from the pieces of random data.

Illustrated in (a) of FIG. **5** is an example of transmission waveforms of the pieces of random data transmitted from the code transmitters **20**_a_ and **20**_b_. Illustrated in (b) of FIG. **5** are a partially enlarged view of (a) of FIG. **5** and an example of the fingerprint.

The code transmitters **20**_a_ and **20**_b_ each transmit the piece of random data at different timings independently of each other ((a) of FIG. **5**).

As illustrated in (b) of FIG. **5**, these pieces of random data are transmitted asynchronously. Transmission of a single piece of random data is completed when the 8-bit random data ("01011011" from the code transmitter **20**_a_, or "01011010" from the code transmitter **20**_b_) preceded by the start bit ("1") (on a left end in the drawing) and followed by the parity bit and the stop bit which is at a tail end (on a right end in the drawing) has been transmitted.

The code receiver **30** receives the two pieces of random data illustrated in (b) of FIG. **5**, appends the random data "01011010" from the code transmitter **20**_b_ to the random data "01011011" from the code transmitter **20**_a_ to thereby generate a 16-bit fingerprint "0101101101011010".

The configuration of the terminal device **40** is described next.

FIG. **6** is a block diagram illustrating the configuration of the terminal device **40**.

The terminal device **40** includes a computer that includes a central processing unit (CPU) **42**, a read only memory (ROM) **44** to which a program is written, and a random access memory (RAM) **46** for temporarily storing data, a wireless communication unit **48**, and a serial communication unit **49**.

The terminal device **40** also includes an authentication unit **420**, a fingerprint acquiring unit **422**, an encrypting unit **424**, a decrypting unit **426**, and a communication control unit **428** as function implementing means that is implemented by the CPU **42** by executing computer programs. Meanwhile, the computer programs can be stored in any desired computer-readable storage medium.

The fingerprint acquiring unit **422** acquires the fingerprint stored in the storage unit **310** of the code receiver **30** connected to the terminal device **40** via the serial communication unit **49**.

The communication control unit **428** transmits the acquired fingerprint and receives a fingerprint transmitted from the other terminal device **40** via the wireless communication unit **48**.

The encrypting unit **424** and the decrypting unit **426** performs fingerprint encryption and fingerprint decryption, respectively, when a fingerprint is to be transmitted and received by the communication control unit **428** using an encryption key.

The authentication unit **420** compares the fingerprint acquired by the fingerprint acquiring unit **422** to the fingerprint received by the communication control unit **428** from the other terminal device **40**, certifies the other terminal device **40** as a recipient with which wireless communication connection is to be established on condition that the fingerprints match, and transmits an encryption key for use in future data communication to the other terminal device **40**.

In the wireless communication system having the configuration described above, when a user switches on the code transmitters **20**_a_ and **20**_b_, the code transmitters **20**_a_ and **20**_b_ continuously output intensity-modulated beams modulated according to the piece of time-varying random data independently of each other.

Next, when the user switches on the code receivers **30**_a_ and **30**_b_ and the terminal devices **40**_a_ and **40**_b_, the code receivers **30**_a_ and **30**_b_ acquire the pieces of random data transmitted from the code transmitters **20**_a_ and **20**_b_, respectively, generate fingerprints based on these pieces of random data, and record the fingerprints.

Subsequently, the terminal devices **40**_a_ and **40**_b_ acquire latest fingerprints from the code receivers **30**_a_ and **30**_b_, respectively, and transmit and receive the acquired fingerprints to and from each other each using its own encryption key α. The terminal devices **40**_a_ and **40**_b_ each authenticate the other terminal device **40**_a_ or **40**_b_ as a communications partner when they have acquired the same fingerprint, exchange their encryption keys β for use in future data exchange, and establish wireless communication connection.

Thus, the terminal devices **40**_a_ and **40**_b_ can automatically acquire and exchange fingerprints without requiring user operation, such as an input of a PIN code, and authenticate a communications partner easily and quickly to thereby establish wireless communication connection.

Meanwhile, code receivers **30**_c_, **30**_d_, and **30**_e_ that, as in an example of arrangement of the terminal devices **40** illustrated in FIG. **7**, are arranged outside the area **24**_a_ where the beams emitted from the code transmitters **20**_a_ and **20**_b_ intersect cannot acquire a piece of random data from any one or both of the code transmitters **20**_a_ and **20**_b_. Accordingly, terminal devices **40**_c_, **40**_d_, and **40**_e_ connected to the code receivers **30**_c_, **30**_d_, and **30**_e_, respectively, cannot acquire the same fingerprint as that acquired by the terminal devices **40**_a_ and **40**_b_ inside the area **24**_a_, and therefore cannot establish communication connection with the terminal devices **40**_a_ and **40**_b_.

As a result, wireless communication connection is established only between the terminal devices **40**_a_ and **40**_b_ that are present in the area **24**_a_ and security against the terminal devices **40**_c_, **40**_d_, and **40**_e_ outside the area **24**_a_ is ensured.

Therefore, even in a case where there are a plurality of meeting spaces adjacent to a wireless coverage (e.g., at distances up to 10 meters) of the terminal devices **40**, it is possible to establish wireless communication connection only between the terminal devices **40** present in an authenticable and connectable physical range (namely, a single meeting space) in a condition where the physical range is explicitly confined by installing the code transmitters **20**_a_ and **20**_b_ in each of the meeting spaces and demarcating each of the meeting spaces as a range where beams emitted from these code transmitters **20**_a_ and **20**_b_ intersect.

Next, procedures for processes to be performed by the wireless communication system are described.

The processes include a fingerprint recording process in which the code receiver **30** generates and records a fingerprint and a communication connection process in which the terminal device **40** authenticates the other terminal device **40** as a communications partner based on the fingerprint generated and recorded by the code receiver **30** and establishes wireless communication connection. The procedures for the processes are individually described below.

Fingerprint Recording Process

The procedure for the fingerprint recording process to be performed by the code receiver **30** is described first according to the flowchart illustrated in FIG. **8**.

When a user switches on the code receiver **30** (Step S**101**), the code receiver **30** causes the photo-receivers **302**_a_ and **302**_b_ to receive signal beams from the code transmitters **20**_a_ and **20**_b_, respectively (Step S**102**). The demodulator **304** demodulates output currents of the photo-receivers **302**_a_ and **302**_b_ into pieces of random data and outputs the pieces of random data each accompanied with source information (information indicating which one of the code transmitters **20**_a_ and **20***b* is a source of each of the piece of random data) to the fingerprint generator **306** (Step S**103**).

The fingerprint generator **306** stores the pieces of random data input from the demodulator **304** in the storage unit **310** on a per-source basis (the code transmitters **20***a* and **20***b*) (Step S**104**), reads out the pieces of random data received from the code transmitters **20***a* and **20***b* and stored in the storage unit **310**, combines these pieces of random data to generate a fingerprint, and outputs the fingerprint to the recording unit **308** (Step S**105**).

Subsequently, the recording unit **308** stores the fingerprint input from the fingerprint generator **306** in the storage unit **310** (Step S**106**). When the number of fingerprints stored in the storage unit **310** exceeds the predetermined number, the recording unit **308** deletes an oldest one of the fingerprints from the storage unit **310** (Step S**107**), and thereafter returns to Step S**102** to repeat processing.

The process described above places the storage unit **310** in a state where the predetermined number of most-recently-generated fingerprints is consistently stored therein.

Meanwhile, this process ends when a user switches off the code receiver **30**.

Communication Connection Process

A procedure for the communication connection process to be performed by the terminal device **40** is described next.

The communication connection process includes a connection request process in which the terminal device **40** transmits a connection request signal (a session request which will be described later) requesting for communication connection to the other terminal device **40**, and a connection response process in which authentication and the like necessary for communication connection are performed in response to receiving a request for communication connection from the other terminal device **40**.

Meanwhile, in the following description, it is assumed that the terminal device **40***a* performs the connection request process, and, in response thereto, the terminal device **40***b* performs the connection response process to facilitate understanding of an authentication protocol (a procedure to be performed to authenticate a communications partner) performed between the terminal devices **40**.

FIG. **9** is a flowchart illustrating the procedure for the communication connection process until when the terminal device **40***a* receives an encryption key β**2** from the terminal device **40***b*. FIG. **10** is a flowchart illustrating the procedure for the communication connection process until when, after the terminal device **40***a* receives the encryption key β**2** from the terminal device **40***b*, the terminal device **40***b* receives an encryption key β**1** from the terminal device **40***a*. FIG. **11** is a flowchart illustrating the procedure for the communication connection process after the terminal device **40***b* receives the encryption key β**1** from the terminal device **40***a*.

In FIGS. **9** to **11**, the flowcharts on the left side illustrate the procedure for the connection request process to be performed by the terminal device **40***a*; the flowcharts on the right side illustrate the procedure for the connection response process to be performed by the terminal device **40***b*; arrows depicted between the right and left flowcharts indicate directions of data exchanged between the terminal devices **40***a* and **40***b* by wireless communication.

The procedures for the connection request process and the connection response process are described below one by one.

Communication Request Process

The procedure for the communication request process is described first according to the flowcharts illustrated on the left side in FIGS. **9** to **11**.

The communication request process starts after a predetermined time interval after power-on of the terminal device **40***a* or in response to an instruction from a user via an operating unit (not shown) of the terminal device **40***a*.

When the connection request process is started, the fingerprint acquiring unit **422** of the terminal device **40***a* reads out from the code receiver **30** a latest fingerprint (referred to as a fingerprint #**1**) of the fingerprints stored in the storage unit **310** of the code receiver **30** via the serial communication unit **49** (Step S**201**). The encrypting unit **424** encrypts the read-out fingerprint #**1** using an encryption key (denoted by α**1**) unique to the terminal device **40***a* (Step S**202**).

The communication control unit **428** of the terminal device **40***a* broadcasts a session request, which is a connection request signal requesting for communication connection, and the encrypted fingerprint #**1** using the wireless communication unit **48** next (Step S**203**).

In response thereto, the terminal device **40***b* receives the session request and the encrypted fingerprint #**1** and starts the connection response process, in which the terminal device **40***b* further encrypts (double encrypts) the received encrypted fingerprint #**1** using an encryption key (denoted by α**2**) of the terminal device **40***b* and transmits the fingerprint to the terminal device **40***a* through Steps S**301** and S**302** of FIG. **9**, which will be described later.

Next, the communication control unit **428** of the terminal device **40***a* receives the double-encrypted fingerprint transmitted from the terminal device **40***b* (S**204**). The decrypting unit **426** of the terminal device **40***a* decrypts the double-encrypted fingerprint using the encryption key α**1** to place it in a state of being encrypted using only the encryption key α**2** (Step S**205**). Subsequently, the communication control unit **428** causes the wireless communication unit **48** to wirelessly transmit the fingerprint #**1** in the state of being encrypted using only the encryption key α**2** to the terminal device **40***b* (Step S**206**).

In response thereto, the terminal device **40***b* performs processing of Steps S**303** to S**309** of FIG. **9**, which will be described later. More specifically, after receiving the fingerprint #**1** in the state of being encrypted using only the encryption key α**2** transmitted from the terminal device **40***a*, the terminal device **40***b* decrypts it using the encryption key α**2** of the terminal device **40***b* to obtain the fingerprint #**1** in plaintext (not encrypted). When a fingerprint that matches the decrypted fingerprint #**1** is stored in the storage unit **310** of the code receiver **30***b* connected to the terminal device **40***b*, the terminal device **40***b* encrypts the encryption key (denoted by β**2**) for use in future communication and a fingerprint #**2**, which is a latest one of the fingerprints stored in the storage unit **310** of the code receiver **30***b*, using the encryption key α**2** of the terminal device **40***b*, and wirelessly transmits the encryption key β**2** and the fingerprint #**2** to the terminal device **40***a*.

Next, the communication control unit **428** of the terminal device **40***a* receives the encrypted encryption key **32** and the fingerprint #**2** transmitted from the terminal device **40***b* (Step S**207**), and proceeds to Step S**208** of FIG. **10**.

A description is given below according to the flowchart illustrated on the left side in FIG. **10**.

Subsequently, the encrypting unit **424** further encrypts (double encrypts) the encrypted encryption key **32** and the encrypted fingerprint #**2** using the encryption key α**1** (Step S**208**) of the terminal device **40***a*. The communication control unit **428** wirelessly transmits the double-encrypted encryption key β**2** and the double-encrypted fingerprint #**2** to the terminal device **40***b* via the wireless communication unit **48** (Step S**209**).

In response thereto, the terminal device **40***b* receives the double-encrypted encryption key β**2** and the fingerprint #**2**, decrypts them using its own encryption key α**2**, and wirelessly transmits the encryption key β**2** and the fingerprint #**2** in a state of being encrypted using only the encryption key α**1** to the terminal device **40***a* through Steps S**310** to S**312** of FIG. **10**, which will be described later.

Next, the communication control unit **428** of the terminal device **40***a* receives the encryption key β**2** and the fingerprint #**2** in the state of being encrypted using only the encryption key α**1** transmitted from the terminal device **40***b* (Step S**210**). The decrypting unit **426** decrypts the received encryption key β**2** and the fingerprint #**2** in the state of being encrypted using only the encryption key α**1** using the encryption key α**1** of the terminal device **40***a* to obtain the encryption key β**2** and the fingerprint #**2** in plaintext (Step S**211**). Furthermore, the communication control unit **428** stores the encryption key β**2** in the RAM **46** (Step S**212**).

Next, the fingerprint acquiring unit **422** of the terminal device **40***a* reads out all fingerprints stored in the code receiver **30***a* (Step S**213**). The authentication unit **420** determines whether the read-out fingerprints include a fingerprint that matches (Step S**214**). When the fingerprints include a fingerprint that matches the fingerprint #**2** (Yes at Step S**214**), the authentication unit **420** certifies the terminal device **40***b* which is a source of the fingerprint #**2** as a communications partner, and instructs the communication control unit **428** to transmit the encryption key β**1** for use in communication to the terminal device **40***a* after establishment of communication connection to the terminal device **40***b* (Step S**215**). On the other hand, when the fingerprints do not include a fingerprint that matches (No at Step S**214**), a communication response process ends without certifying the terminal device **40***b* as a communications partner.

Subsequently, the communication control unit **428** causes the encrypting unit **424** to encrypt the encryption key β**1** for use in communication to the terminal device **40***a* after establishment of communication connection using the encryption key α**1** of the terminal device **40***a* (Step S**216**), thereafter causes the wireless communication unit **48** to wirelessly transmit the encryption key β**1** encrypted using the encryption key α**1** to the terminal device **40***b* (Step S**217**), and proceeds to step S**218** of FIG. **11**.

In response thereto, the terminal device **40***b* receives the encryption key β**1** encrypted using the encryption key α**1**, further encrypts (double encrypts) the encryption key β**1** using its own encryption key α**2**, and wirelessly transmits the double-encrypted encryption key β**1** to the terminal device **40***a* through Step S**313** of FIG. **10** and Steps S**314** and S**315** of FIG. **11**, which will be described later.

A description is given below according to the flowchart illustrated on the left side in FIG. **11**.

Next, the communication control unit **428** of the terminal device **40***a* receives the double-encrypted encryption key β**1** transmitted from the terminal device **40***b* (Step S**218**). The decrypting unit **426** decrypts the received double-encrypted encryption key β**1** using the encryption key α**1** to place the encryption key β**1** in a state of being encrypted using only the encryption key α**2** (Step S**219**). The communication control unit **428** causes the wireless communication unit **48** to wirelessly transmit the encryption key β**1** in the state of being encrypted using only the encryption key α**2** to the terminal device **40***b* (Step S**220**), at which the connection request process ends.

In response thereto, the terminal device **40***b* receives the double-encrypted encryption key β**1** in the state of being encrypted using only the encryption key α**2**, decrypts the encryption key β**1** using its own encryption key α**2** to obtain the encryption key β**1** in plaintext, and thereafter stores the encryption key β**1** in the RAM **46** through Steps S**316** to S**318** of FIG. **11**, which will be described later. The communication response process performed by the terminal device **40***b* is thus completed and communication connection between the terminal devices **40***a* and **40***b* is established. More specifically, the terminal devices **40***a* and **40***b* exchange data using their own encryption keys β**1** and β**2** by encrypting and decrypting data using the encryption key β**2** for data transmission from the terminal device **40***b* to the terminal device **40***a* and encrypting and decrypting data using the encryption key β**1** for data transmission from the terminal device **40***a* to the terminal device **40***b*.

Communication Response Process

The procedure for the communication response process is described next according to the flowcharts illustrated on the right side in FIGS. **9** to **11**. As described above, it is assumed in the following description that the communication response process is performed by the terminal device **40***b* in response to the connection request process performed by the terminal device **40***a*.

The communication response process starts when the communication control unit **428** of the terminal device **40***b* receives the session request and the encrypted fingerprint #**1** broadcasted from the terminal device **40***a* (Step S**203** of FIG. **9**).

When the connection response process is started, the encrypting unit **424** further encrypts (double encrypts) the encrypted fingerprint #**1** received by the communication control unit **428** using the encryption key α**2** of the terminal device **40***b* (Step S**301**). The communication control unit **428** wirelessly transmits the double-encrypted fingerprint #**1** to the terminal device **40***a* via the wireless communication unit **48** (Step S**302**).

Next, the communication control unit **428** of the terminal device **40***b* receives the fingerprint #**1** in the state of being encrypted using only the encryption key α**2** transmitted from the terminal device **40***a* at Step S**206** of FIG. **9** (Step S**303**). The decrypting unit **426** decrypts the fingerprint #**1** in the encrypted state using the encryption key α**2** of the terminal device **40***b* to obtain the fingerprint #**1** in plaintext (Step S**304**).

Subsequently, the fingerprint acquiring unit **422** of the terminal device **40***b* reads out all the fingerprints stored in the code receiver **30***b* (Step S**305**). The authentication unit **420** determines whether the read-out fingerprints include a fingerprint that matches the fingerprint #**1** (Step S**306**). When the fingerprints include a fingerprint that matches (Yes at Step S**306**), the authentication unit **420** certifies the terminal device **40***a* which is a source of the fingerprint #**1** as a communications partner, and instructs the communication control unit **428** to transmit the encryption key β**2** for use in communication to the terminal device **40***b* after establishment of communication connection to the terminal device **40***a* (Step S**307**). On the other hand, when the fingerprints do not include a fingerprint that matches (No at Step S**306**), the communication response process ends without certifying the terminal device **40***a* as a communications partner.

Next, the communication control unit **428** of the terminal device **40***b* causes the encrypting unit **424** to encrypt the encryption key β**2** for use in communication to the terminal device **40***b* after establishment of communication connection and a latest one (referred to as the fingerprint #**2**) of the fingerprints stored in the code receiver **30***b* using the encryption key α**2** of the terminal device **40***b* (Step S**308**). The communication control unit **428** wirelessly transmits the encrypted encryption key β**2** and the fingerprint #**2** to the terminal device **40***a* via the wireless communication unit **48** (Step S**309**), and proceeds to Step S**310** of FIG. **10**.

A description is given below according to the flowchart illustrated on the right side in FIG. **10**.

Subsequently, the communication control unit **428** of the terminal device **40***b* receives the encryption key β**2** and the fingerprint #**2** in the state of being double-encrypted using the encryption keys α**1** and α**2** transmitted from the terminal device **40***a* at Step S**209** of FIG. **10** (Step S**310**). The decrypting unit **426** decrypts the encryption key β**2** and the fingerprint #**2** in the state of being double-encrypted using the encryption key α**2** of the terminal device **40***b* to obtain the encryption key β**2** and the fingerprint #**2** in the state of being encrypted using only the encryption key α**1** (Step S**311**). Subsequently, the communication control unit **428** wirelessly transmits the encryption key β**2** and the fingerprint #**2** in the state of being encrypted using only the encryption key α**1** to the terminal device **40***a* via the wireless communication unit **48** (Step S**312**).

Next, the communication control unit **428** of the terminal device **40***b* receives the encryption key β**1**, which is encrypted using the encryption key α**1**, transmitted from the terminal device **40***a* at Step S**217** of FIG. **10** (Step S**313**), and proceeds to Step S**313** of FIG. **11**.

A description is given below according to the flowchart illustrated on the right side in FIG. **11**.

Subsequently, the encrypting unit **424** of the terminal device **40***b* further encrypts (double encrypts) the encrypted encryption key β**1** received at Step S**313** of FIG. **10** using the encryption key α**2** of the terminal device **40***b* (Step S**314**). The communication control unit **428** wirelessly transmits the double-encrypted encryption key in to the terminal device **40***a* via the wireless communication unit **48** (Step S**315**).

Next, the communication control unit **428** of the terminal device **40***b* receives the encryption key β**1** in the state of being encrypted using only the encryption key α**2** transmitted from the terminal device **40***a* at Step S**220** of FIG. **11** (Step S**316**). The decrypting unit **426** decrypts the encryption key β**1** in the encrypted state using the encryption key α**2** of the terminal device **40***b* to obtain the encryption key β**1** in plaintext (Step S**317**). After the obtained encryption key β**1** in plaintext is stored in the RAM **46** (Step S**318**), the connection response process ends.

Next, a wireless communication system according to a second embodiment of the present invention is described.

In the wireless communication system, the code transmitters **20** of the wireless communication system according to the first embodiment are installed in advance in a meeting room or the like as parts of existing indoor illuminating devices.

According to the present embodiment, it is not necessary to additionally install the code transmitters **20** in a place, such as a meeting room, where temporary connection authentication is required; each user can only bringing the terminal device **40** to which the code receiver **30** is connected into a meeting room or the like to establish wireless communication connection with the other terminal device **40** in the same meeting room.

FIGS. **12**A and **12**B illustrate an example of installation of the code transmitters **20** in the wireless communication system according to the second embodiment of the present invention.

FIG. **12**A is a diagram illustrating an example in which the light sources **214** of the code transmitters **20** are arranged in indoor illuminating devices. FIG. **12**B is a diagram illustrating a wireless communication area (area where wireless communication connection is to be established) formed by arrangement of the light sources **214** illustrated in FIG. **12**A.

In FIG. **12**A, light sources **214***a* and **214***b*, **214***c* and **214***d*, and **214***e* and **214***f* are arranged in three indoor illuminating devices **50***a*, **50***b*, and **50***c*, respectively, which are fluorescent lamps, for example, on both widthwise sides of the indoor illuminating devices **50***a*, **50***b*, and **50***c* at substantially centers of inclined inner-side surface portions (light reflection surfaces) extending along a longitudinal direction. Each of these light sources **214***a* to **214***f* is a part of one of the code transmitters **20** that are independent of each other. Meanwhile, constituents (not shown) of the code transmitters **20** other than the light sources **214***a* to **214***f* may be arranged in close vicinity of the light sources **214***a* to **214***f* or remotely arranged at one location together.

FIG. **12**B is a diagram illustrating the indoor illuminating devices **50***a*, **50***b*, and **50***c* illustrated in FIG. **12**A and a space stretched therebelow.

Illumination areas **23***a* to **23***f* of beams emitted from the light sources **214***a* to **214***f* are provided in the space stretched below the indoor illuminating devices **50***a*, **50***b*, and **50***c*. An area **24***b*, an area **24***c*, and an area **24***d* where the illumination areas **23***a* and **23***b*, the illumination areas **23***c* and **23***d*, and the illumination areas **23***e* and **23***f* intersect, respectively, are provided in spaces immediately below the indoor illuminating devices **50***a*, **50***b*, and **50***c*.

Furthermore, an area **24***e* where the illumination areas **23***a* and **23***d* intersect and an area **24***f* where the illumination areas **23***c* and **23***f* intersect are provided in spaces below the areas **24***b* to **24***d*.

Each of the areas **24***e* and **24***f* among the areas **24***b* to **24***f* can be assigned as a wireless communication area as an area having a range that is sufficiently wide for holding a meeting or the like therein, for example.

Meanwhile, in the example illustrated in FIGS. **12**A and **12**B, a configuration in which the light sources **214** of the code transmitters **20** are attached to portions of light reflection plates of the indoor illuminating devices **50** is employed; however, the configuration is not limited thereto. For example, in a case where LED illuminating devices are used as the indoor illuminating devices **50**, LED light sources used as the indoor illuminating devices **50** themselves can be used as the light sources **214** of the code transmitters **20**.

Next, a wireless communication system according to a third embodiment of the present invention is described.

This wireless communication system uses, in contrast to the wireless communication system according to the first embodiment that includes the two code transmitters **20** (**20***a* and **20***b* of FIG. **1**), three or more the code transmitters **20**. The code transmitters **20** are arranged so as to surround an area (wireless communication area) where wireless communication connection is to be established and in such a manner that illumination beams from all the code transmitters **20** intersect in the area.

Furthermore, the code receiver **30** causes the two photoreceivers **302***a* and **302***b* to receive pieces of random data transmitted from the three or more code transmitters **20** and generates a fingerprint based on at least two pieces of random data.

According to the present embodiment, the code transmitters **20** are arranged so as to surround the wireless communication area. Accordingly, it is possible to indicate the range where wireless communication is established in a visually easy-to-know manner. More specifically, the code transmitters **20** serve as landmarks indicating a range of a “security zone” where security-provided wireless communication can be carried out through connection authentication using the fingerprint. Users can perform communication connection with feeling of security. Meanwhile, it is possible to further increase an effect as the landmarks of the "security zone" by arranging each of the code transmitters **20** as being attached to a movable support unit, e.g., a self-standable stand.

FIG. **13** is a diagram illustrating an example of installation of the code transmitters **20** in the wireless communication system according to the third embodiment of the present invention.

In FIG. **13**, four code transmitters **20***c* to **20***f* are attached to self-standable stands **26***a* to **26***d*, respectively. Furthermore, the code transmitters **20***c* to **20***f* are arranged so as to surround an area where wireless communication is to be established and in such a manner that illumination areas **22***c* to **22***f* of all the code transmitters **20***c* to **20***f* intersect in the area.

FIG. **14** is a diagram illustrating an example of arrangement of the code receivers **30** in the area surrounded by the code transmitters **20***c* to **20***f* illustrated in FIG. **13**.

FIG. **14** is a plan view of the area. The two code receivers **30***c* and **30***d* are arranged in the area surrounded by the code transmitters **20***c* to **20***f*.

Each of users of the code receivers **30***c* and **30***d* can adjust an orientation of the substrate **32** (FIG. **4**), which is provided in each of the code receivers **30***c* and **30***d* and to which the two photo-receivers **302***a* and **302***b* are attached, so that the code receivers **30***c* and **30***d* receive at least two same pieces of random data from the code transmitters **20***c* to **20***f*. This allows the code receivers **30***c* and **30***d* to generate a same fingerprint, and accordingly wireless communication connection can be established between the terminal device **40** (not shown) connected to the code receiver **30***c* and the terminal device **40** (not shown) connected to the code receiver **30***d*.

Next, a wireless communication system according to a fourth embodiment of the present invention is described.

This system is configured in such a manner that the wireless communication system according to the third embodiment includes a code receiver including four photo-receivers arranged so as to be capable of receiving beams coming from four orthogonal directions and the terminal device **40** connected to the code receiver. In this system, at least one of the two terminal devices **40** that establish wireless communication connection is connected to the code receiver including the four photo-receivers.

In the wireless communication system according to the third embodiment, the code receivers **30***c* and **30***d* cannot generate a same fingerprint when the orientation of the substrate **32** (FIG. **4**) provided in each of the code receivers **30***c* and **30***d* is non-adjustable in such a situation where the orientations of the substrates **32** (FIG. **4**) provided in the code receivers **30***c* and **30***d* are mutually orthogonal, the code receiver **30***c* receives only illumination beams from the code transmitters **20***c* and **20***d*, and the code receiver **30***d* receives only illumination beams from the code transmitters **20***e* and **20***f* in FIG. **14**, for example.

In contrast, in the present embodiment, the code receiver including the four photo-receivers is connected to the at least one of the two terminal devices **40** that carry out wireless communication connection. The code receiver including the four photo-receivers can receive all the illumination beams from the code transmitters **20***c* to **20***f*, and therefore can generate a fingerprint based on every combination of two pieces of random data of four pieces of random data transmitted from the code transmitters **20***c* to **20***f*.

Accordingly, even in a case where the code receiver **30** is capable of illumination beams from only two code transmitters (e.g., the code transmitters **20***c* and **20***d*) of the code transmitters **20***c* to **20***f*, the code receiver including the four photo-receivers can generate a same fingerprint as a fingerprint generated by the code receiver **30** without exception. As a result, even in a case where a user cannot adjust an orientation in which the code receiver **30** is installed, wireless communication connection can be established between the terminal device **40** connected to the code receiver **30** and the terminal device **40** connected to the code receiver including the four photo-receivers.

FIG. **15** is a diagram illustrating a configuration of the wireless communication system according to the fourth embodiment of the present invention.

This wireless communication system includes the code transmitters **20***c* to **20***f* arranged so as to surround the area where wireless communication is to be established, the code receiver **30** arranged in the area where beams emitted from the code transmitters **20***c* to **20***f* intersect, a code receiver **60** including the four photo-receivers, and the terminal device **40***c* and the terminal device **40***d* connected to the code receiver **30** and the code receiver **60**, respectively.

FIG. **16** is a block diagram illustrating the configuration of the code receiver **60**.

The code receiver **60** includes four photo-receivers **602***a*, **602***b*, **602***c*, and **602***d*, a demodulator **604**, a fingerprint generator **606**, a recording unit **608**, a storage unit **610** made of up a RAM or the like, and a serial communication unit **612**.

The photo-receivers **602***a* to **602***d* receive the intensity-modulated beams, which are beams emitted from the code transmitters **20***c* to **20***f*, respectively, and convert the beams into electric signals (intensity-modulation signals). Photodiode, phototransistors, or the like suited for an emission wavelength of the light source **214** of the code transmitter **20** can be used as the photo-receivers **602***a* to **602***d*.

FIG. **17** is a diagram illustrating an example of arrangement of the photo-receivers **602***a* to **602***d*.

The photo-receivers **602***a* to **602***d* are arranged on four side surface portions, respectively, of a rectangular solid block **62** so that the photo-receivers **602***a* to **602***d* can receive beams from mutually-orthogonal four directions.

The demodulator **604** demodulates the electric signals output from the photo-receivers **602***a* to **602***d* and outputs each piece of random data (8-bit data) transmitted from the code transmitters **20***c* to **20***f* accompanied with source information (information indicating from which one of the code transmitters **20***c* to **20***f* is a source of the piece of random data) to the fingerprint generator **606**.

The fingerprint generator **606** stores the pieces of random data output from the demodulator **604** on a per-source basis (namely, for each of the code transmitters **20***c* to **20***f* separately) in the storage unit **610**. Thus, the latest pieces of random data transmitted from the code transmitters **20***c* to **20***f* are consistently stored in the storage unit **610**. Thereafter, the fingerprint generator **606** generates all fingerprints, each of which is formed by extracting arbitrary two pieces of random data from the pieces of random data transmitted from the code transmitters **20***c* to **20***f* and stored in the storage unit **610** and combining them, and outputs the fingerprints to the recording unit **608**.

As a result of the operations described above, the fingerprint generator **606** generates a new fingerprint at a point in time where any one of the pieces of random data transmitted from the code transmitters **20***c* to **20***f* is changed.

Meanwhile, timing when the fingerprint is to be generated is not limited to the point in time of the present embodiment where any one of the pieces of random data transmitted from the code transmitters **20***c* to **20***f* is changed, but can be a point in time where all the pieces of random data transmitted from the code transmitters **20***c* to **20***f* are changed.

Next, the recording unit **608** stores fingerprints generated by the fingerprint generator **606** in the storage unit **610** in an order in which they are generated. In addition, an oldest one of the fingerprints is deleted from the storage unit **610** when the number of the stored fingerprints exceeds a predetermined number, thereby causing the predetermined number of fingerprints to be consistently held in the storage unit **610**.

In addition, the serial communication unit **612** exchanges data with the terminal device **40** via a USB or the like serial bus.

Next, a wireless communication system according to a fifth embodiment of the present invention is described.

This system is configured in a manner such that the wireless communication unit **48** of the terminal device **40** in the wireless communication systems according to the first to fourth embodiments carries out wireless communication by what is called ultra wideband (UWB) wireless using a bandwidth of 500 MHz or more or a bandwidth of 20% of a center frequency or more.

UWB is a wireless communication scheme defined by an output voltage limited to small-distance communication and appropriate for large-amount-data communication in a situation free from interference with another wireless device that uses a same frequency range. According to the present embodiment, the terminal device **40** includes the wireless communication unit **48** that carries out wireless communication over UWB. Accordingly, a small-distance large-amount-data wireless communication system can be constructed by easily connecting the terminal devices **40** in proximity to each other.

As described above, according to the present embodiment, it is possible to generate a fingerprint that is common only among the terminal devices **40** that are at a same place at same time, thereby making it possible to perform authentication that is common among the terminal devices **40** easily and quickly without requiring an operation by an operator (user). Furthermore, even in a range up to 10 meters, for example, when there is a region to be differentiated (in a case where extents of adjacent meeting spaces are within 10 meters or the like) in the range, it is possible to explicitly confine an authenticable and connectable physical range for each of the regions as a region where beams emitted from the code transmitters **20** intersect.

According to the embodiments, it is possible to establish communication connection in a temporarily-used area, such as a meeting room, by performing authentication of the terminal devices easily and quickly.

Although the invention has been described with respect to specific embodiments for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art that fairly fall within the basic teaching herein set forth.

The invention claimed is:

1. A wireless communication system, comprising:

a plurality of code transmitters each configured to transmit a time-varying code, the time-varying codes transmitted from the code transmitters being different from each other;

a plurality of code receivers each configured to receive the time-varying codes transmitted from the code transmitters and generate a fingerprint based on the received time-varying codes, the fingerprint being unique to a space where the time-varying codes are receivable; and

a plurality of terminal devices configured to establish wireless communication connection therebetween with authentication, the terminal devices being connected to the code receivers, respectively, wherein

each of the terminal devices includes

a fingerprint acquiring unit configured to acquire the fingerprint from the code receiver connected thereto,

a wireless communication unit configured to transmit and receive the fingerprint via wireless communication, and

an authentication unit configured to authenticate, as a communications partner, another one of the terminal devices if the fingerprint received by the wireless communication unit from the another one of the terminal devices matches the fingerprint acquired by the fingerprint acquiring unit from the code receiver connected thereto.

2. The wireless communication system according to claim **1**, wherein

each of the code transmitters includes

a light source having a predetermined beam angle, and

a modulating unit configured to modulate a beam emitted from the light source with the time-varying code of the each of the code transmitters, and

each of the code receivers includes

a photo-receiver configured to receive the beam emitted from the light source of the code transmitter, and

a demodulating unit configured to demodulate an output of the photo-receiver into the time-varying code.

3. The wireless communication system according to claim **1**, wherein each of the code transmitters includes a random number generator configured to generate the time-varying code based on a random number generated by the random number generator.

4. The wireless communication system according to claim **1**, wherein the wireless communication is ultra wideband wireless communication carried out using a bandwidth of 500 MHz or more or a bandwidth of 20% of a center frequency or more.

5. The wireless communication system according to claim **2**, wherein the light source of the code transmitter is arranged in an indoor illuminating device.

6. The wireless communication system according to claim **2**, wherein the light source of the code transmitter is an indoor illuminating device.

7. The wireless communication system according to claim **2**, wherein

the number of the code transmitters is three or more, and

the code transmitters are arranged in a manner that the beams emitted from the light sources of the code transmitters intersect.

8. The wireless communication system according to claim **7**, wherein each of the code transmitters is arranged on a movable support unit.

9. The wireless communication system according to claim **7**, wherein

the number of the code transmitters is four,

at least one of the code receivers includes four photo-receivers each configured to receive the beams emitted from the light sources of the code transmitters, respectively, and

at least one of the terminal devices that mutually establish the wireless communication connection is connected to the code receiver including the four photo-receivers.

10. A terminal-device authentication method in a wireless communication system including a plurality of terminal devices configured to establish wireless communication connection therebetween with authentication, the terminal-device authentication method comprising:

transmitting, by each of the code transmitters, a time-varying code, the time-varying codes transmitted from the code transmitters being different from each other;

receiving, by a plurality of code receivers connected to the terminal devices respectively, the time-varying codes transmitted from the code transmitters;

generating, by each of the code receivers, fingerprint based on the received time-varying codes, the fingerprint being unique to a space where the time-varying codes are receivable;

acquiring, by each of the terminal devices, the fingerprint from the code receiver connected thereto;

transmitting, by each of the terminal devices, the fingerprint via wireless communication;

receiving, by each of the terminal devices, the fingerprint via the wireless communication; and

authenticating, as a communications partner of one of the terminal devices, another one of the terminal devices if the fingerprint received from the another one of the terminal devices matches the fingerprint acquired by the one of the terminal devices.

* * * * *